EVOLUTION AND CLASSIFICATION OF THE LATE CRETACEOUS–EARLY TERTIARY GASTROPOD *PERISSITYS*

W.P. Popenoe and L.R. Saul[1]

ABSTRACT. A new neogastropod family Perissityidae is proposed for several lineages of American Pacific Coast gastropods having species of early Senonian age that are very similar but late Senonian species that are disparate. Four genera of Perissityidae are discussed: the type genus *Perissitys* Stewart, 1927, *Pseudocymia* new genus, *Murphitys* new genus, and *Christitys* new genus. Seven species are assigned to *Perissitys: P. cretacea* (Cooper), *P. elaphia* new species, *P. brevirostris* (Gabb) (type species), *P. pacifica* new species, *P. colocara* new species, *P. stantoni* (Stewart), and *P. stewarti* (Zinsmeister). The genus ranges in age from Coniacian through early Paleocene; and its evolutionary changes include reduction and disappearance of tubercles on the inner apertural margins, comparative increase in length of the siphonal canal, and extension of the inner lip callus to finally encompass nearly the entire shell in the later Maastrichtian, followed subsequently by reduction of this callus in the Paleocene.

Pseudocymia new genus, with type species *P. aurora* new species includes *P.*(?) *aitha* new species, *P.*(?) *cahalli* new species, and *P.*(?) *kilmeri* new species and ranges from Turonian into the Maastrichtian. Evolutionary changes in *Pseudocymia* include reduction of denticles on the inner apertural margins and elongation of the entire shell.

Murphitys new genus comprises *M. michaeli* new species (type species), *M. corona* new species, and *M. madonna* new species, and ranges from Coniacian to Maastrichtian. Its evolutionary changes include increasing angularity of whorl profile, development of columellar folds, and expansion of the outer lip to form a rimmed aperture.

Christitys new genus, comprising *C. delta* new species, *C. medica* new species (type species), and *C. martini* new species ranges from Coniacian to Campanian. Its evolutionary changes include development of a more pyriform shape and reduction of the denticulations of the outer lip.

Sequence and rate of morphologic change in these molluscan groups have significance in principles of gastropod taxonomy and utility for correlation.

INTRODUCTION

Erection of a family, Perissityidae, to encompass the enigmatic neogastropod lineages of *Perissitys, Cophocara,* and "*Hindsia nodulosa* (Whiteaves)" was first suggested by W.P. Popenoe at the 1971 Cordilleran section meeting of the Geological Society of America (Popenoe, 1971, p. 179; Saul, 1971, p. 189). Popenoe intended to propose the family and describe half of the perissityid genera; Saul was to (and will) describe the remainder. This paper treats those genera and species of Perissityidae that Popenoe intended to describe. Some problems of biostratigraphic correlation, which we believe are now resolved, delayed the writing of this paper beyond the time allotted to Popenoe; the paper has, therefore, been completed by Saul.

The genera *Perissitys* and *Cophocara* were described by Stewart (1927), but neither was assigned to a family, both being consigned to "doubtful systematic position." Earlier, Cossmann (1901) and later, Wenz (1943), Erickson (1974), and Zinsmeister (1983) placed these genera near *Tudicla,* an association that may be more of form than of phylogeny. As traced in this paper the evolutionary sequence of which *Perissitys brevirostris* (Gabb, 1864) and *Cophocara stantoni* Stewart, 1927, form a part, extends from Coniacian into early Selandian (middle Paleocene). End members of this lineage would scarcely be included in the same family by most systematists were intermediate stages unknown.

Three new genera, *Pseudocymia, Murphitys,* and *Christitys,* are represented in the Coniacian by species resembling *Perissitys cretacea* (Cooper). These genera diverged from *Perissitys* and from each other in the Santonian, and by Campanian time all were represented by species of decidedly different aspect.

Six previously described West Coast species are unhesitantly allotted to the family Perissityidae: *Perissitys brevirostris* (Gabb, 1864), *Fusus kingii* Gabb, 1864, *Cophocara stantoni* Stewart, 1927, *C. stewarti* Zinsmeister, 1983, *Fas-*

1. At the time that the research described in this paper was conducted, both authors were with the Department of Earth & Space Sciences, University of California, Los Angeles. Popenoe died in 1981. Saul is currently with the Invertebrate Paleontology Section of the Natural History Museum of Los Angeles County.

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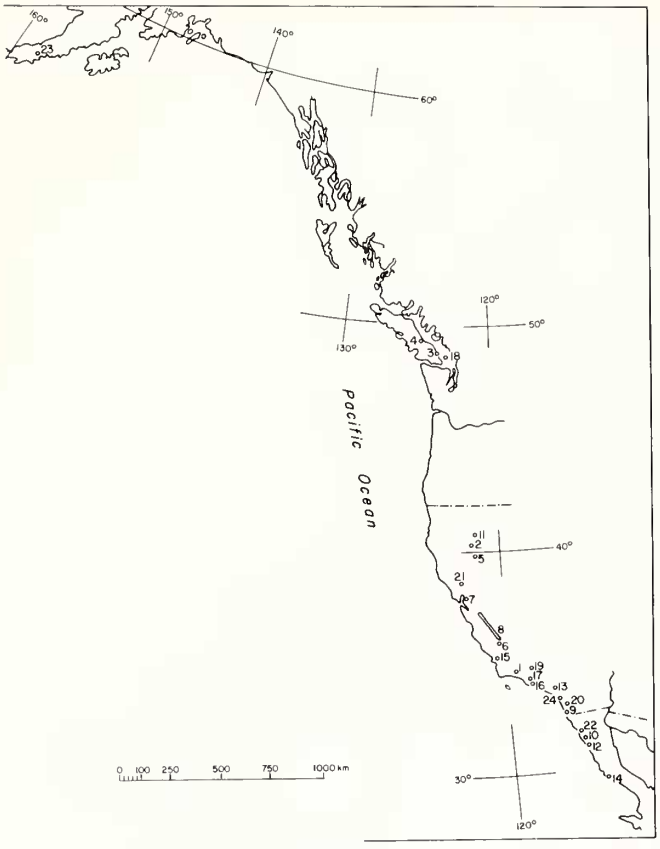


Figure 1. Index map to geographic occurrence of perissityids described in this paper. **1.** Agua Caliente Canyon, San Rafael Mts., Santa Barbara Co., California. **2.** Antelope Creek, Mill Creek, and Tuscan Springs, Tehama Co., California. **3.** Benson (= Brannan Creek), Blundon Point, and Elkhorn Creek, Nanaimo Basin, Vancouver Island, British Columbia. **4.** Browns River, Comax Basin, Vancouver Island, British Columbia. **5.** Butte Creek, Chico Creek, and Pentz, Butte Co., California. **6.** Cottonwood Creek in Cholame Valley Quadrangle, Monterey Co., California. **7.** Deer Valley and vicinity of Martinez, Contra Costa Co., California. **8.** East side of the Diablo Range from Stanislaus Co. south to Fresno Co., California. **9.** Point Loma, San Diego Co., California. **10.** Punta San Jose, Baja California Norte, Mexico. **11.** East of Redding, Shasta Co., California. **12.** San Antonio del Mar and Johnson's Ranch, Baja California, Mexico. **13.** Santa Ana Mountains, Orange Co., California. **14.** Santa Catarina Landing area, Baja California, Mexico. **15.** Lake Nacimiento, southern Santa Lucia Range and Santa Margarita Lake, La Panza Range, San Luis Obispo Co., California. **16.** Santa Monica Mountains, Los Angeles Co., California. **17.** Simi Hills, Los Angeles and Ventura cos., California. **18.** Sucia Island, San Juan Co., Washington. **19.** Warm Springs Mountain, northwestern San Gabriel Mts., Los Angeles Co., California. **20.** Vicinity of Carlsbad, San Diego Co., California. **21.** Rumsey Hills, Yolo Co., California. **22.** Punta Banda, Baja California, Mexico. **23.** Chignik Lagoon, Alaska Peninsula, Alaska. **24.** East of San Juan Capistrano, Orange Co., California. Place names mentioned in text listed alphabetically: **1.** Agua Caliente Canyon; **2.** Antelope Creek; **11.** Bear Creek; **13.** Bee Canyon; **17.** Bell Canyon; **3.** Benson (= Brannan) Creek; **3.** Blundon Point; **4.** Browns River; **21.** Buckeye Creek; **5.** Butte Creek; **15.** Cantinas Creek; **20.** Carlsbad; **5.** Chico Creek; **23.** Chignik Lagoon; **8.** Coalinga; **11.** Clover Creek; **6.** Cottonwood Creek in Cholame Valley Quadrangle **17.** Dayton Canyon; **7.** Deer Valley; **3.** Departure Bay; **8.** Diablo Range; **3.** Elkhorn Creek; **12.** Johnson's Ranch; **8.** Laguna Seca Hills; **17.** Lang Ranch; **7.** Martinez; **2.** Mill Creek; **11.** Morley; **11.** Oak Run; **8.** Oil Canyon; **11.** Old Cow Creek; **8.** Ortigalita Creek; **7.** Pacheco; **8.** Pacheco Pass; **8.** Panoche Hills; **5.** Pentz; **11.** Pine Timber Gulch; **9.** Point Loma; **11.** Price Hollow; **22.** Punta Banda; **14.** Punta Canoas; **10.** Punta San Jose; **11.** Redding area; **7.** Riggs Canyon; **21.** Rumsey Hills; **11.** Salt Creek; **12.** San Antonio del Mar; **24.** San Juan Capistrano; **21.** Sand Creek; **13.** Santa Ana Mts.; **14.** Santa Catarina Landing area; **15.** Santa Margarita Lake; **16.** Santa Monica Mts.; **17.** Simi Hills; **18.** Sucia Island; **11.** Swede Basin; **2.** Tuscan Springs; **19.** Warm Springs Mt.; **23.** Whaler's Creek.

ciolaria nodulosa Whiteaves, 1874, = *Hindsia nodulosa* Whiteaves, 1879, and *Sistrum* (*Ricinula*?) *cretaceum* Cooper, 1896. Probably *Nekewis simiensis* Zinsmeister, 1983, and possibly *N. io* (Gabb, 1864), *N. washingtoniana* (Weaver, 1912), and *N. nehalemensis* (Anderson & Martin, 1914) are also perissityids. T. Kase has provided plaster casts of specimens of some Japanese perissityids, including *Surculites*? cf. *S.*? *fusoides* Nagao, 1939, and *Pseudoperissitys bicarinata* Nagao & Otatume, 1938. Additionally, descriptions and figures suggest that *Trachytriton sachalinensis* Schmidt, 1873 [= *Serrifusus*? *sachalinensis* (Schmidt) in Hayami & Kase (1977, p. 63) non *Serrifusus sachalinensis* (Nagao, 1932)], *T. duiensis* Schmidt, 1873, *Pyropsis* sp. indet. of Nagao (1939), *Pyrifusus* (*Neptunella*) *kawakamiensis* Nagao, 1939, and *Fusus* (s.l.) *volutodermoides* Nagao, 1939, from the northwestern Pacific are Perissityidae, as is *Perissolax brevirostris* Gabb of Martin (1926) from Alaska. *Fusus dusenianus* Wilckens, 1907, *Struthiolariopsis*? *tumida* Wilckens, 1907, and *Heteroterma praecursor* (Wilckens, 1907) from the upper Cretaceous of southern Patagonia resemble perissityids, but the aperture of none has been described. *Perissitys*? sp. A and B of Erickson (1974), however, from the Fox Hills Formation of North Dakota do not show any characteristics of this family. We have not seen specimens of the undescribed *Cophocara* sp. of Sohl (1967, p. 34) from the upper Campanian of Wyoming. In previous classifications species assignable to the Perissityidae have been distributed among Cassididae, Thaididae, Buccinidae, Fasciolariidae, Xancidae or Vasidae, Tudiclidae, and Turridae.

Much of this diverse family assignment results from the divergent evolutionary paths followed by the several lineages. The lineage with changes best documented by specimens is that of *Perissitys*. Adequate specimens, sufficiently well distributed through the stratigraphic sections, indicate style, pattern, pace, and rate of evolution within this group.

Abbreviations used with catalog and locality numbers are:

ANSP = Academy of Natural Sciences of Philadelphia
CAS = California Academy of Sciences, San Francisco
CGS = Canada Geological Survey
CIT = California Institute of Technology (collections now at LACMIP)
LACMIP = Los Angeles County Museum of Natural History, Invertebrate Paleontology

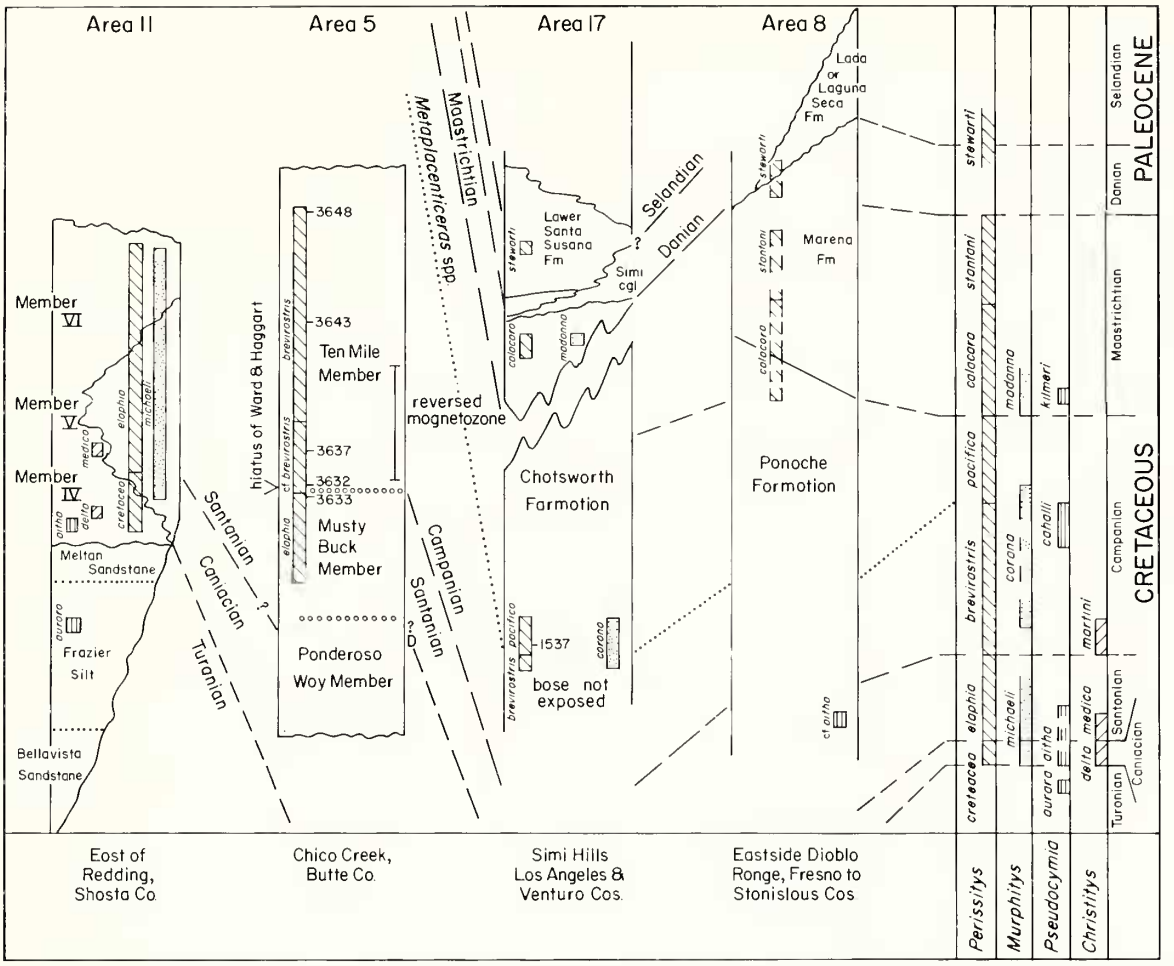


Figure 2. Stratigraphic occurrence of *Perissitys, Murphitys, Christitys,* and *Pseudocymia* in four California sections: Redding area (area 11), based on Popenoe, 1943, and Matsumoto, 1960; Chico Creek (area 5), after Saul, 1983; Simi Hills (area 17), after Saul, 1983; and east side Diablo Range (area 8), simplified from Saul, 1983. The columns are not all to the same scale. The Redding area, Simi Hills, and east side Diablo Range columns are composites and each represents a considerable area; the Chico Creek column is based on outcrops along Chico Creek. Campanian reversed magnetozone (Chron 33r) is from Ward et al. (1983). The position of some fossil localities is indicated by locality number.

LSJU = Stanford University (collections now at CAS)
SDSNH = San Diego Society of Natural History
UCB = University of California, Berkeley
UCBMP = University of California, Berkeley, Museum of Paleontology
UCLA = University of California, Los Angeles (collections now at LACMIP)
UCR = University California, Riverside
USGS = United States Geological Survey
USNM = United States National Museum of Natural History

OCCURRENCE

Specimens of *Perissitys, Pseudocymia, Murphitys,* and *Christitys* have been collected from more than 200 localities from Alaska to Baja California, Mexico. Only seven areas have provided stratigraphic successions of species: in British Columbia on Vancouver Island (Figure 1, area 3), and in California east of Redding (area 11), along Chico Creek (area 5), on the east side of the Diablo Range (area 8), near Warm Springs Mountain (area 19), in the Simi Hills (area 17), and in the Santa Ana Mountains (area 13). Stratigraphic position of the perissityid occurrences at Redding, Chico Creek, Simi Hills, and in the Diablo Range is diagrammed in Figure 2. The probable chronologic ranges of species, derived from their stratigraphic occurrences are plotted on Figure 3 with the position of some Pacific West Coast zonal indicators.

Stratigraphic nomenclature of the Cretaceous east of Redding (area 11) has been revised by Haggart (1986). Popenoe (1943), in a progress report, placed the strata in six Members I–VI. Type sections were left undesignated, but disposition of the members has been shown on maps (e.g., Popenoe, 1943; Matsumoto, 1960; Trujillo, 1960). M.V. Kirk (*fide*

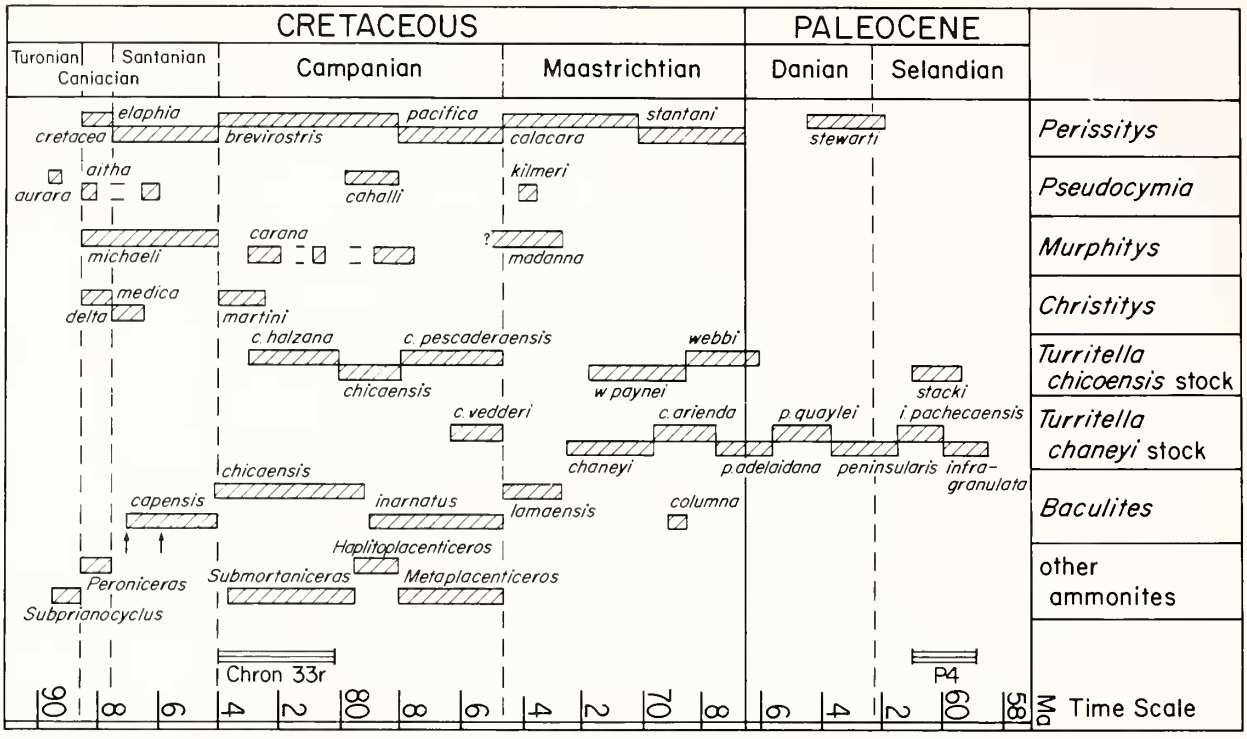


Figure 3. Geologic range of species of perissityids described in this paper, *Turritella chaneyi* and *T. chicoensis* stocks and some ammonites fitted to the time scale of Palmer (1983) and Berggren et al. (1985a). Arrows indicate approximately the range allotted to *B. capensis* by Haggart and Ward (1984) and Haggart (1984). *Turritella* zonation from Saul (1983), and Campanian reversed magnetozone, Chron 33r, from Ward et al. (1983). In Harland et al. (1982, p. 74) Chron 33r is dated as 78.53–82.93 Ma.

Matsumoto, 1960, p. 4) suggested the name Redding Formation for these members. Popenoe (in Jones, et al., 1978) named Members I–III, in ascending order Bellavista Sandstone, Frazier Siltstone, and Melton Sandstone. J.M. Haggart (1986) delimited the outcrop area of the Redding Formation and named Members IV–VI. In his Bear Creek Sandstone he includes Member III and part of Member V of Popenoe (1943) and the Melton Sandstone of Popenoe (in Jones et al., 1978); in the Hooten Gulch Mudstone the mudstones of Members IV and VI of Popenoe (1943), and in the Oak Run Conglomerate part of Member V of Popenoe (1943). Virtually all of the Redding area specimens used in this study were collected by Popenoe, and the recorded locality descriptions reflect his view of the stratigraphy. Conversion to Haggart's stratigraphy would require a more detailed map than that available in Haggart (1986, fig. 4) and would result in a complete revision of recorded names. As Popenoe is senior author of this paper and his view of Haggart's revision unknown, the Redding area column (Figure 2, area 11) is a modification of Popenoe (1943) compatible with his last expressed opinions. Despite the differences regarding stratigraphic nomenclature between Popenoe and Haggart, age assignments are mainly in accord, and stratigraphic position of the specimens within sections exposed in the several creeks is not disputed. The differences arise in recognizing lithologic units present from section to section in the several creeks.

Perissityid gastropods are found in coarse- to very fine-grained sandstone. *Perissitys* is most abundant in medium- to fine-grained sandstone, and is associated with very shallow-water molluscan assemblages characterized by species of *Yaadia, Meekia,* and *Cymbophora;* slightly deeper water assemblages characterized by *Calva, Pterotrigonia,* and *Tenea;* and softer bottom assemblages characterized by *Crassatella, Clisocolus, Cucullaea, Turritella,* and *Anchura. Perissitys* regularly occurs with naticids and may, like them, have been confined to soft substrates (Taylor et al., 1980, p. 380). Its occurrence in several assemblages suggests a fairly wide water-depth range. Perissityids are usually a minor component of these faunas and are inferred to have been predators. Although morphologic changes in the *Perissitys* lineage are apparent, there are neither correlative substrate nor marked faunal association changes suggestive of adaptation to a new habitat. The modifications of form in *Perissitys* may be further adaptations to an infaunal, predatory life style, but not to change in habitat.

The largest specimens of *Perissitys* are from near the top of the Chico Formation on Chico Creek (area 5)—diameter over 45 mm; Pleasants Sandstone Member of the Williams Formation, Bee Canyon, Santa Ana Mountains (area 13)—diameter 51.5 mm; Moreno Formation near Ortigalita Creek (UCB loc. A-6618) (area 8)—diameter about 35 mm; and the top of the Great Valley Series near Martinez (area 7)—diameter 36 mm. Large specimens of *Perissitys* spp. have thus been found in beds of mid Campanian through mid Maastrichtian age.

The geologically oldest species are the most geographically

restricted; whereas those of Campanian age are most widely distributed. However, Campanian sandstones crop out more widely than those of Coniacian–Santonian age, and the absence or abundance of perissityids may be an artifact of the geological record rather than an indication of their place of origin and a record of dispersal. The geologically oldest (Turonian–Coniacian) perissityids from western North America are all from east of Redding (Figure 1, area 11). Ages of Japanese perissityids are roughly contemporaneous with those of the West Coast. Japanese perissityids from the Upper Yezo Group, *Pyropsis* sp. indet. of Nagao, 1939, = *Tudicla* (*Perissitys*) sp. in Hayami & Kase (1977); *Pyrifusus* (*Neptunella*) *kawakamiensis* Nagao, 1939, = *Rhombopsis*? *kawakamiensis* (Nagao) in Hayami & Kase (1977); *Surculites fusoides* Nagao, 1939; and *Fusus* (s.l.) *volutodermoides* Nagao, 1939, are considered by Hayami and Kase (1977) to be of Coniacian or Santonian age. *Trachytriton sachalinensis* Schmidt, 1873, = *Serrifusus*? *sachalinensis* (Schmidt) in Hayami & Kase (1977) and *T. duiensis* Schmidt, 1873, = *S.*? *duiensis* (Schmidt) in Hayami & Kase (1977) from Sachalin are "Campanian or thereabouts" (Hayami and Kase, 1977). *Pseudoperissitys bicarinata* Nagao & Otatume, 1938, is Campanian or Maastrichtian (Hayami and Kase, 1977).

The earliest and most characteristic perissityids are from the North Pacific and this family may be of North Pacific origin as well as of predominantly North Pacific occurrence. Zinsmeister (1983) indicates confamiliality for *Cophocara, Heteroterma, Nekewis,* and *Tudiclana;* and, as *Heteroterma* spp. have been recognized in the New Zealand Paleocene and Patagonian Cretaceous (Finlay and Marwick, 1937), perissityid distribution apparently extended to South America and New Zealand in the latest Cretaceous and Early Tertiary.

MORPHOLOGIC CHANGE

The earliest perissityids are similar in shape and in aperture and differ mainly in sculpture (Figures 5–9, 104). The latest perissityids are, however, dissimilar, each lineage having evolved a distinctly different aspect. And in most lineages the geologically youngest form differs markedly from the oldest. With the exception of columellar folds (commonly ranked as a generic or familial feature) the characters that change in a lineage are those usually considered to be of no more than specific importance. Sequential ordering of species in the lineages is based upon stratigraphic superposition of specimens in perissityid-bearing sections and biostratigraphic correlation of these and other deposits in which perissityids occur. Although perissityid occurrences in these deposits are spotty, sufficient specimens at close enough intervals have been obtained to make patterns of change within the group apparent. Surprisingly, between the five similar Coniacian species and their disparate Campanian descendents, there are no more than three species in any lineage. In each lineage the species arise by phyletic transitions; lineage splitting, because of the trends in the development of some characteristics within each lineage, results in recognizable genera. Formation of new morphologic species through phyletic transitions is more than four times as common as is lineage splitting; divergence between lineages is more prevalent than paral-

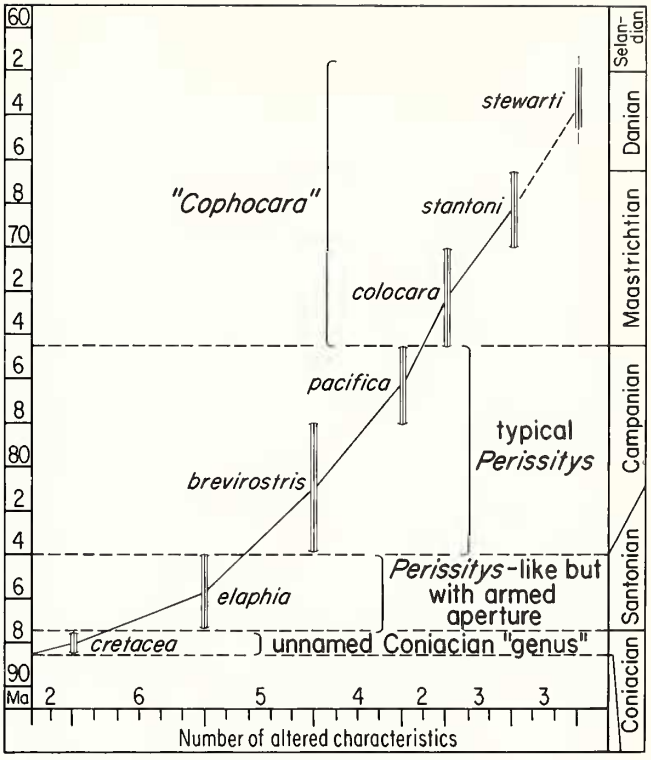
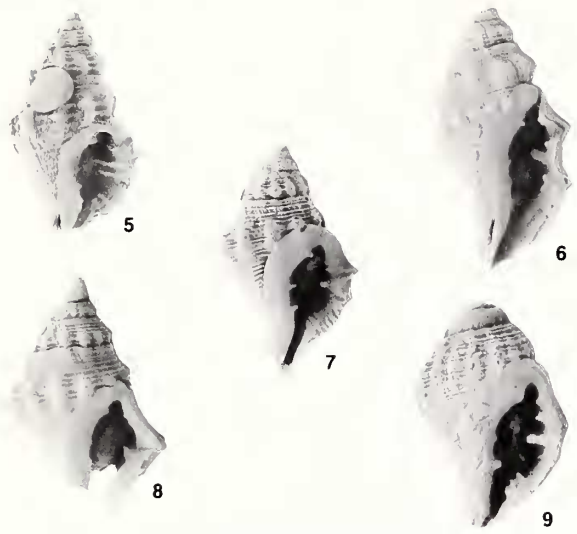


Figure 4. Plot of time versus changed characteristics in the *Perissitys* lineage. Bars indicate recognized range of each specific taxon. Brackets show range of possible genera if the genera were defined according to characteristics commonly considered to be of generic importance. Because there are specimens of intergrading form between the recognized species a sloping line is drawn connecting the mid-point of each range bar. The more horizontal the line the faster the species is changing; the more nearly vertical the slope, the more the species approaches stasis. Two changes are diagrammed within *cretacea* during the Coniacian; six accumulate during the earlier part of the Santonian between *cretacea* and *elaphia;* five during the later Santonian and earliest Campanian between *elaphia* and *brevirostris;* four through the early and mid Campanian between *brevirostris* and *pacifica;* two during latest Campanian and earliest Maastrichtian between *pacifica* and *colocara;* and three from early Maastrichtian into late Maastrichtian between *colocara* and *stantoni.* Three changes are diagrammed between *stantoni* and *stewarti* although the fossil record between these two is incomplete.

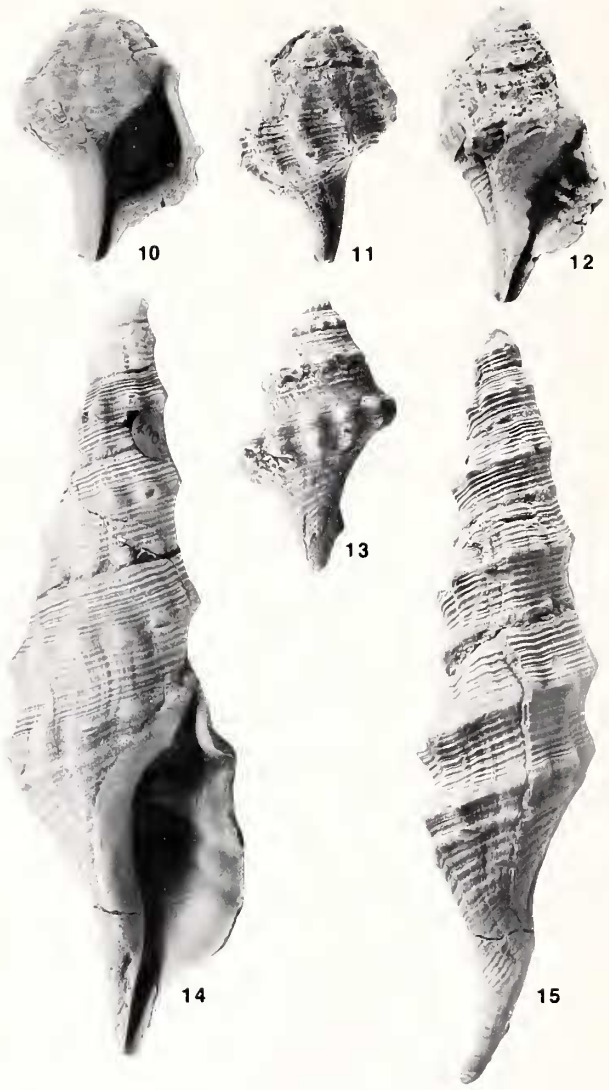
lellism, and convergence is rare. To determine whether the style of evolution is punctuated or gradual, the rate fast or slow, and its pace steady or varied requires a specimen-rich lineage such as *Perissitys.* Plotting morphologic change against biostratigraphic zonations combined with a time scale, provides apparent rate and pace of change in the *Perissitys* lineage (Figure 4).

PATTERNS OF CHANGE

Divergenee in the four lineages *Perissitys, Pseudocymia, Murphitys,* and *Christitys* (compare Figures 7, 104, 9, and 8 to 93, 100, 127, 160, and 182) is accomplished through mod-



Figures 5–9. Coniacian perissityid species. **5.** *Pseudocymia*(?) *aitha* new species, holotype, ×1, UCLA 39440 from CIT loc. 1007. **6.** "*Fusus*" aff. "*F.*" *kingii* Gabb, hypotype, ×1, LACMIP 7245 from CIT loc. 1007. **7.** *Perissitys cretacea* (Cooper), neotype, ×1, UCLA 59588 from UCLA loc. 4104. **8.** *Christitys delta* new species, holotype, ×1.5, UCLA 59455 from UCLA loc. 4209. **9.** *Murphitys michaeli* new species, paratype, ×1.5, LACMIP 7271 from CIT loc. 1230.



Figures 10–15. Three species of mid Campanian age from the three most complete perissityid lineages. **10, 11.** *Perissitys brevirostris* (Gabb), hypotype, ×1.5, UCLA 59661 from CIT loc. 1400. **12, 13.** "*Hindsia nodulosa* (Whiteaves)," hypotypes, ×1; **12,** UCLA 39464 from CIT loc. 1158; **13,** UCLA 39466 from CIT loc. 1402. **14, 15.** "*Fusus*" cf. "*F.*" *kingii* Gabb, hypotype, ×1, LACMIP 7246 from UCLA loc. 7003.

est modifications to different sets of characteristics in each lineage. The degree of differentiation achieved by incremental changes within three perissityid lineages across 10 million years can be seen by comparing Figures 5–9 of Coniacian species with Figures 10–15 of mid Campanian forms. Amount of alteration within each lineage is suggested by comparing Figure 7 to 93 and 100, 104 to 127, 9 to 160, and 8 to 182. Although the morphologic differences between *Perissitys cretacea* (Figure 7), *P. brevirostris* (Figure 10), and *P. stantoni* (Figure 93) have been considered to warrant recognition of distinct genera, these forms result from phyletic transition within a lineage. The differences between species resulting from a lineage split (Figures 5 and 7) are not greater than those between adjacent species in a lineage (Figures 7 and 27).

The genus *Pseudocymia* changes from shortly fusiform in shape to moderately elongate fusiform. The pseudofolds on the columella are reduced as is the posterior sinus in the outer lip. Unifying features include the several nearly equal, distinct spiral ribs that override short, strong axial ribs, a siphonal fasciole, and the thickened outer lip with several subequal, liriform denticulations. The genus *Christitys* develops a more pyriform shape with a broader, more expanded periphery upon which the number of strong spiral ribs is reduced, and weaker outer lip denticulations. Unifying features include the posterior sinus of the growth line, a relatively abapical position for the strong outer lip denticulations, and the columellar fold at the base of the previous whorl. The genus *Murphitys* develops a roundly expanded inner lip, a growth line straightened across the ramp with the sinus displaced posteriorly and becoming adjacent to the suture, and more nodulose axial sculpture combined with finer spiral sculpture. Unifying features include the two columellar folds, the rimmed outer lip, and the plumply buccinifform shape. The genus *Perissitys* changes from buccinifform to pyriform, develops an expanded inner lip that eventually envelops most of the spire and last whorl in callus, and reduces and then eliminates columellar pseudofolds and outer lip denticulations.

The sums of these changes are impressive, espeeially so because the differences between species are not large. Absence of specimens, regarded as constituting a species, from the geological record would produce a punctuational style to the

evolution of these lineages; absence of two such adjacent species would prevent recognition of the lineage.

A gap between the early late Turonian *Pseudocymia aurora* and the five Coniacian perissityid species (Figures 5–9) leaves unrepresented a short period of time during which, if these five species are derived from *P. aurora,* there is an increase in species diversity. The Coniacian–Santonian *Perissitys* record following this gap is of relatively rapid evolution (Figure 4). Similar rates of evolution could produce the five Coniacian perissityid species—*P. cretacea, M. michaeli, P.*(?) *aitha, C. delta,* and "*F.*" aff. "*F.*" *kingii*—from *P. aurora.* Near the Coniacian–Santonian boundary, another lineage split and increase in species diversity is suggested by the similarity of Coniacian *Christitys delta* (Figures 8, 165–168) and Santonian *C. medica* (Figures 169–170, 172–177) to the early Santonian member of the "*Hindsia nodulosa*" lineage (Saul, in prep.). These possible increases in species and generic diversity involve no greater morphological modifications from the putative ancestors than are present between species of *Perissitys.* Additional such alterations render these lineages recognizable as distinct genera. The possibility of proliferation of species at the margins of geographic ranges (Shuto, 1974) is suggested by the presence of perissityids in Japan. Thus, although the style of morphologic change in West Coast perissityids is predominantly gradual, apparent punctuation may be developed in other geographic areas.

Evolution of "specific" characteristics in the *Perissitys* lineage has sufficed to produce morphologic dissimilarity regardable as of "generic" degree, but the style of change remains gradual within and between species of *Perissitys* and the characteristics evolve independently. Individual specimens have some but not all features more advanced than do other specimens from the same locality. A collection from a single locality probably represents more than one generation of mollusks, resulting in variety of form, but the heterogeneous expression of the evolving characteristics suggests heterochronous spread through the populations of incremental alterations.

The changes within and between species of *Perissitys* are modest. The bucciniform *Perissitys cretacea* becomes slightly shorter spired, and the inner lip broadens posteriorly.

P. elaphia has one or two more strong peripheral ribs than does *P. cretacea.* Typically in *P. elaphia* the parietal lip expands to cover the apertural face of the last whorl, there is an additional medial dentiele within the outer lip, the posterior growth-line sinus is diminished, the anterior canal is lengthened, and *P. elaphia* has a more pyriform shape. The earliest *P. elaphia* have, however, a bucciniform shape, a moderate expansion of the parietal lip, only a small additional medial denticle within the outer lip, and no notable change in the anterior canal. Although there is usually a third spiral rib about the periphery, it is weaker than the other two. The third peripheral rib is rapidly strengthened upsection and some late early Santonian *P. elaphia* (Figure 38) have four strong peripheral spirals. The parietal callus also expands adapically so that *P. elaphia* from the *Inoceramus schmidti* horizon of Mill Creek, the *Baculites capensis* Zone on Chico Creek and later Santonian localities of the Redding area (e.g., UCLA loc. 4217 on Clover Creek) have callus up the apertural face of the spire (Figure 40). Additionally, these late Santonian *P. elaphia* are of more pyriform shape as the whorl becomes more strongly contracted immediately anterior to the abapical strong peripheral spiral. Finally, the youngest *P. elaphia* have weakly developed pseudofolds and denticulations. The species cannot, therefore, be considered to be in a state of stasis. Morphologic variation within each locality collection suggests that the changes are gradually acquired and not abruptly developed.

Perissitys brevirostris lacks the apertural ornaments of *P. elaphia,* has a longer, straighter canal, a shorter spire, no more than three strong peripheral ribs, and a more expansive parietal lip. The earliest Campanian *P. brevirostris* (Figure 43) differs from typical *P. brevirostris* and resembles late Santonian *P. elaphia* in having a relatively high ramp and a more angulate peripheral profile. Although specimens found through 600+ m of the Ten Mile Member of the Chico Formation on Chico Creek (area 5) are identified as *P. brevirostris,* typical *P. brevirostris* with the longer straighter canal and usually rounder whorl profile are found through the upper 427 m of this thickness (Figures 54, 56). Despite some variation of whorl profile, spacing of the peripheral ribs, and height of spire, *P. brevirostris* is morphologically relatively stable through this section, in contrast to the greater number of changes in *P. elaphia,* which has been found through only 200+ m of the Musty Buck Member (Figure 2).

The transition from *P. brevirostris* to *P. pacifica* involves shortening of the spire, crowding of the peripheral spirals to form a narrower and more angulate periphery, and increased coverage of the shell by the expanded callus. Many specimens from the Chatsworth Formation in Bell Canyon (area 17) have two strong peripheral spirals, typical of *P. pacifica,* but the rounder whorl profile of *P. brevirostris* (Figure 61). In the upper part of its stratigraphic range *P. pacifica* gradually acquires the characteristics of *P. colocara* applying increased callus over the shell and developing less prominent peripheral spirals and nodes.

So many specimens of *P. colocara* have been identified as *Cophocara stantoni* that the differences between *P. pacifica* and *P. colocara* might be expected to be much greater. The differences consist, however, mainly of the addition of more callus and the further reduction of peripheral spirals and nodes, trends which ultimately result in *P. stantoni.* The more enveloping callus on *P. colocara* is typically deposited, at intervals, thickly near the aperture. When further growth occurs, this lump of callus distorts the growth spiral and causes the shell to appear deformed. Some specimens of *P. colocara* (Figures 84, 85) either produced less of a callus coat or were interrupted before they completed their coating and in their seminudity resemble *P. pacifica.* Although an enveloping callus coat gives an impression of definite specific difference, the coat developed over a period of time during which more individuals are more callused and specimens with less coating are rarer in the collections.

P. colocara and *P. stantoni* are difficult to distinguish because both are coated with callus. The crowding of the peripheral spiral ribs reaches its ultimate in *P. stantoni,* and

only one rib is dominant; the callus coat is thicker and applied more evenly; the spire is consistently short, and the periphery less angulate.

Specimens from the late Maastrichtian beds at the base of the San Francisquito Formation on Warm Springs Mountain (area 19) (Figure 95) and from the Lower Laguna Seca Formation, UCB loc. A-3262 (area 8) (Figure 96) have characteristics intermediate between *P. stantoni* and *P. stewarti,* but are, unfortunately, poorly preserved. UCB loc. A-3262 has not yielded turritellas, and *Perissitys* has not yet been recovered in association with *Turritella peninsularis adelaidana* Merriam. The oldest turritellas with which *P. stewarti* is associated are late *Turritella quaylei* and *T. peninsularis* and are probably not older than late Danian (Saul, 1983), but specimens from UCB loc. A-3262 and some other localities in the Panoche Hills (area 8) may be from older horizons. *P. stewarti* differs most evidently from *P. stantoni* in having two well-developed peripheral spiral rows of nodes, giving it a blunt, biangulate periphery. It also has a shorter spire and a thinner callus coating.

Perissitys is well represented in the fossil record and changes within as well as between its species are documented by specimens. Of the four genera, *Perissitys* supplies most evidence for style and rate of change. Four of the *Perissitys* species have fossil records that are stratigraphically complete enough to give an indication of the pace of change.

RATE OF MORPHOLOGIC CHANGE

The range of *Perissitys* is Coniacian to early Selandian (Paleocene). The Coniacian age is based on ammonite zonation and the Selandian on turritellid zonation. Several time scales have been proposed recently for this interval. Stage lengths vary on the various time scales, and estimates of chronologic duration of *Perissitys* species and the rates of change within the lineage are dependent on the time scale chosen. The DNAG 1983 Time Scale (Palmer, 1983) for this interval is in close agreement with a 1984 version of Berggren et al. (1985b), Kent and Gradstein (1985), and Berggren et al. (1985b) except for the placement of the Danian–Selandian boundary. If this boundary is put at 62.3 Ma (Berggren et al., 1985a; Berggren et al., 1985b) rather than at 63.6 Ma (Palmer, 1983), *Perissitys stewarti* is probably mainly Danian in occurrence. The range of *P. stewarti* (Figure 3) is plotted with respect to its association with *Turritella peninsularis* and is independent of the position of the Danian–Selandian boundary. At the earlier end of the *Perissitys* lineage, *P. cretacea* ranges through the Pacific West Coast Coniacian Stage defined by ammonite correlations. The early Campanian marine magnetic anomaly 33–34, Chron 33r, encompasses approximately 260 m of the Ten Mile Member in the Chico Creek section (Ward et al., 1983) (see Figure 2). Early *P. brevirostris* is found through this part of the Chico Creek section and Chron 33r is coincident with the earlier part of the range of *P. brevirostris.* Chron 33r is considered to have begun shortly after the Santonian–Campanian boundary and to last for 3.5–5 Ma. It is dated at 78.53 to 82.93 Ma by Harland et al. (1982, p. 74) but is considered to be nearly 2 Ma older on the DNAG 1983 Time Scale (Palmer, 1983).

Based on these correlations and plotted against the DNAG 1983 Geologic Time Scale, *Perissitys* has a duration of roughly 26 Ma (Figure 3). Seven successive specific taxa are named in this lineage. Were a constant rate of change assumed each species would have a time span of 3.7 Ma, or slightly more than one-third the 10 Ma considered to be the mean species duration for gastropods (Stanley, 1985, p. 16). *Perissitys cretacea* (Cooper), however, has been recognized only from the Coniacian which may be no longer than 1 Ma (Obradovich and Cobban, 1975, p. 46). But, as *P. cretacea* may not be descended from the only pre-Senonian perissityid herein recognized, *Pseudocymia aurora* new species of early late Turonian age, the earliest possible appearance of *P. cretacea* remains undefined and its range may have extended into the Turonian and exceeded one million years. *Perissitys elaphia* new species occurs through the Santonian, which is estimated to represent about 3.5 Ma (Palmer, 1983). Specimens identified as *P. brevirostris* (Gabb) are of early to mid Campanian age, and the taxon ranges through approximately 6 Ma. *Perissitys pacifica* new species is of late Campanian age and thus has a duration of roughly 4 Ma. *P. pacifica* changes less dramatically and more slowly than does *P. elaphia* but more rapidly than *P. brevirostris.* Early Maastrichtian *P. colocara* new species also has a probable duration of 4 Ma. It is succeeded near the middle of the Maastrichtian by *P. stantoni* (Stewart), which has a duration of at least 3.5 Ma. Unfortunately specimens of *Perissitys* have not yet been found in deposits certainly recognized as earliest Paleocene and the biochron of *P. stantoni* (Stewart) is probably not completely known, nor is that of the Paleocene species *P. stewarti* (Zinsmeister).

The number of altered characteristics in the genus *Perissitys* are plotted against geologic time in Figure 4. Each of the above-mentioned differences between species is given equal weight. The slope of the line is an indication of the rate of change in *Perissitys.* Change is most rapid through the Coniacian–Santonian and slowest through the early to mid Campanian. Although *Pseudocymia aurora* may or may not be ancestral to *Perissitys cretacea,* there are essentially four morphologic changes between the two. *P. cretacea* has fewer denticles on its outer lip, a slightly longer canal, a deeper posterior sinus, and a periphery marked by two strong spirals. Had *Pseudocymia aurora* been included on Figure 4, the slope of line between it and *Perissitys cretacea* would have been similar to that between *P. cretacea* and *P. elaphia.* Forms intermediate between *P. aurora* and *P. cretacea* are, however, unknown.

The *Perissitys* lineage exhibits its most rapid accrual of morphologic change through the Coniacian and Santonian, but the other lineages, although not as well documented, do not evince equal degrees of evolution. The least change recognized for this same Coniacian–Santonian interval is in the *Murphitys* lineage whose species *M. michaeli* ranges through the Coniacian and Santonian stages.

In the *Perissitys* lineage the varied pace of gradual change produces morphologic differences of generic degree, but the recognition of different genera has not oeeurred at times of relatively rapid evolution and between species of short temporal duration. Previous workers have identified *P. pacifica*

as *P. brevirostris* and *P. colocara* as *Cophocara stantoni,* thus recognizing a generic distinction between these two new species, each of which has a duration of approximately 4 Ma. Occasionally late *P. pacifica* has been identified as *Cophocara stantoni* and early *P. colocara* as *P. brevirostris* reflecting independent and unequal development of characteristics. Perceived generic differences are not, therefore, dependent on rapid evolution nor great morphologic change.

If the average duration of a gastropod species is 10 Ma (Stanley, 1985), the perissityids are evolving more rapidly than is usual for their class. Their morphologic changes do not appear to reflect major habitat changes, although the different lineages probably had somewhat different requirements. Judging from their occurrence in the geologic record, *Pseudocymia, Murphitys,* and *Christitys* were less widely adapted than *Perissitys.* The continuing direction of changes, such as the increasing envelopment of the spire by the inner lip callus and the lengthening of the anterior siphonal canal in *Perissitys,* produce the distinct morphologies of this group. That so much directional change occurred during the Late Cretaceous, a time of relative stability, suggests biological rather than physieal pressure. Greater arthropod predation and increasingly infaunal habitat of bivalves (Vermeij, 1977) that may have been prey of the perissityids would both have promoted infaunal adaptations in these siphonate gastropods.

CLASSIFICATION

Gastropods that we propose to include in the family Perissityidae form a morphologically compact group in the Coniacian, and five species of that age could readily be assigned to a single genus (Figures 5–9). Lineages based on these five species, traced through the Late Cretaceous, evolve new forms by modifying species-defining characteristics to the extent that by the mid Campanian the three most complete lineages are represented by species—*Perissitys brevirostris* (Gabb), "*Fusus*" ef. "*F.*" *kingii* Gabb, and "*Hindsia nodulosa*" (Whiteaves) (Figures 10–15)—which have not been considered congeneric, nor assignable to the same family. Clearly the approach of the systematist will affect the ordinal, familial, generic and even specific placement of these fossils. The classification presented here has its basis in stratigraphically ordered specimens collected from Late Cretaceous and early Paleocene sequences of the Pacific Coast of North America. The successions of fossils assigned to the perissityids document a part of the Late Cretaceous siphonate gastropod radiation (Sohl, 1964; Taylor et al., 1980).

SPECIES

A paleontological species is a morphologic species, and if there are gaps in the record of a lineage, the preserved segments of the lineage may readily be recognized as species. If there are no gaps, or the gaps are short relative to the rate of evolution of the lineage, a grading continuum of morphologies may result. This is the case with *Perissitys.* Because of the range of variation present at any stratigraphic level, and the changes between levels, *Perissitys* specimens identified by comparison to those from super- and subjacent strata are alike enough to be identified as being of the same species. If artificial gaps are created, however, by comparing specimens of early Campanian age to those of Coniacian or mid Maastrichtian age, three easily distinguishable species, sufficiently different to have been previously allotted to three genera (Figure 4), are apparent. The West Coast lineage of *Perissitys* is an evolutionary continuum, and its species are arbitrarily named segments, but arbitrary only in the sense that there are no abrupt morphologic changes in this continuum despite the distinctness of the end members. Each lineage has several characteristic features that vary and evolve independently, producing a clinal rather than punctuational series of phenotypes. Species recognition is dependent upon an aggregate of changing features, and each remains recognizable for various lengths of time (Figures 3, 4).

Should these forms be considered to be species if speciation events are absent? This paper deals only with specimens from the West Coast of North America, but there are perissityids in Japan and possible perissityids in New Zealand and Chile. Although the present West Coast record is one of phyletic transitions, the lineages may have split near the geographic range margins of the species. The North American perissityids pass through sufficient morphologic changes that segments of these lineages must be considered to be species. Additionally, the named species have biostratigraphic integrity and are useful for correlating Late Cretaceous and Early Tertiary sections.

GENUS

If the genus *Perissitys* were narrowly restricted to those species having the apertural characteristics of the type species, *P. brevirostris* (Gabb), only it and *P. pacifica* new species could be included therein. Of the remaining species, *P. cretacea* (Cooper) could be placed in a new genus along with the four contemporary species of Figures 5–9; *P. elaphia* might constitute a new monotypic genus; and *P. colocara* new species, *P. stantoni* (Stewart), and *P. stewarti* (Zinsmeister) would make up *Cophocara* (Figure 4). Such genera are horizontal in that their distribution tends to lie along restricted time planes and resemble many Recent genera in which aggregations of similar but distinct species are recognized, but their phylogenetic relationships through time are not. The perissityid genera recognized are linear (or vertical) genera. Retaining a single generic name for each lineage organizes the species; recognizing successive chronospecies provides gnomons along the genetic line.

FAMILY

Perissityidae are, or are derived from, bucciniform gastropods that have two folds or pseudofolds on the columella, a parietal welt or denticulations near the posterior end of the aperture, a posterior sinus to the growth line, and strong median denticulations within the outer lip. The outer lip flares anteriorly and is thickened by a varix. Impressions of former outer-lip thickenings and denticulations are found on steinkerns, even though such varices may not be obvious on the shell exterior. Compared to turritellid lineages of the same period and time span, the perissityid lineages evolve rapidly

and divergently, each lineage following its own course and arriving at forms suggestive of disparate families. The apertures of early perissityids resemble those of columbellinids, and several late Jurassic columbellinid trends—constricted and then flared apertures, denticulate outer and inner apertural lips, inner lip callus expanded and covering one-half to the entire exterior of the shell (Taylor et al., 1980)—resemble those of perissityids. These suggest a columbellinid derivation, possibly within the Early Cretaceous.

Perissitys stewarti (Zinsmeister, 1983) from the Paleocene is pyriform in shape with a moderately long, nearly straight anterior canal, and lacks apertural pseudofolds and denticulations; it resembles Tudiclidae. *Pseudocymia*(?) *kilneri* new species of early Maastrichtian age is subfusiform in shape with a short, flexed anterior canal, strong denticulations on the outer lip, and weak pseudofolds on the columella, and resembles tropical Buccinidae. *Christitys martini* new species of early Campanian age is pyriform in shape, has weak denticulations on the outer lip and a fold on the columella. Its form, except for that of its outer lip, is similar to some Vasidae. *Murphitys madonna* new species, of early Maastrichtian age, is angulate bucciniform in shape and has a thickened outer lip and two folds on the columella. Except for these columellar folds it resembles some Cymatiidae. Zinsmeister (1983, p. 1297) includes those forms with short to moderately elevated spire, i.e., *Perissitys, Cophocara,* and *Heteroterma,* in Tudiclidae, and moves the higher spired *Nekewis* from the Turridae to the Tudiclidae because of its similarities to *Heteroterma.* None of these genera have the tudiclid fold at the base of the columella; neither *Heteroterma* nor *Nekewis* has the characteristic expanded inner lip of *Tudicla spirillus* (Linnaeus), and all have an eye-shaped rather than a well-rounded aperture. The growth line of *Heteroterma* and *Nekewis* is sinused posteriorly and resembles that of *Christitys* (Figures 166 and 176) and "*Hindsia nodulosa* (Whiteaves)" (Figure 13), and these genera are closer to Perissityidae than to Tudiclidae. *Tudiclana simulator* Findlay & Marwick, 1937, which resembles *Perissitys brevirostris* but lacks the subsutural welt, is described has having a low fold at the base of its columella, and it may belong with *Tudicla* as indicated by Finlay and Marwick (1937). Abbott (1959, p. 20–471) suggests that *Tudicla* is usually included in the Vasidae because its overall shape resembles that of *Tudicula* spp., although there is no anatomical evidence to support this placement. Thus Finlay and Marwick (1937) and Zinsmeister (1983) may well be correct in divorcing the Tudiclidae from the Vasidae. Although we do not consider *Perissitys* to be a tudiclid, the Tudiclidae and Perissityidae may be more closely related than either is to the Vasidae.

SUPERFAMILY

At the family level the perissityids are grouped together because of their early characteristics in common, several of these characteristics also serving to distinguish them from other families, but at the next hierarchical level we place them in the superfamily into which these diverging lineages appear to evolve. Placing them in Muricacea of Ponder (1973) would be simplest as he includes within the Muricacea the Buccinacea and Volutacea of Wenz (1941). This large polymorphic superfamily grouping tends, however, to obscure a number of relationships. The families Muricidae, Thaididae, Magilidae, and Columbariidae, which constitute the Muricacea of Wenz (1941) and Taylor and Sohl (1962), form a distinct group within Ponder's Muricacea. With Muricacea constituted as of Taylor and Sohl (1962), and the Buccinacea and Volutacea of Wenz (1941) and Taylor and Sohl (1962) regarded as distinct, choice of superfamily placement for the Perissityidae is increased. The Perissityidae have little in common with Late Cretaceous muricaceans and more similarity to buccinaceans and volutaceans. Buccinaceans and volutaceans appear in the late Early Cretaceous and both are relatively common in the Late Cretaceous (Taylor et al., 1980). Wenz (1943) and Zinsmeister (1983) place *Perissitys* and *Cophocara* in the Volutacea, apparently because the pyriform shape resembles that of *Tudicla,* which was included in the Volutacea by Thiele (1929), Wenz (1943), and others, and presumably by Taylor and Sohl (1962) who, following Wenz, placed the Vasidae—in which *Tudicla* is often included—in the Volutacea. Clearly the earliest perissityids have neither a volutid shape nor columella folds similar to those of volutes, whereas volutes from the same beds already display characteristic volute morphology. *Perissitys* evolves toward a shape similar to that of some genera included by Wenz in the Vasidae [e.g., *Pyropsis* (Conrad, 1860; Sohl, 1964), *Tudicla* (Röding, 1798; Abbott, 1959), and *Tudiclana* (Finlay and Marwick, 1937)], but Sohl (1964) later moved the Vasinae, including *Tudicla,* to the Buccinacea, and it is within the Buccinacea that the Perissityidae are placed.

As already indicated perissityids resemble the Cymatiidae and the Columbellinidae. Cossmann (1904), Wenz (1940), and Sohl (1960) assigned the Columbellinidae to the Strombacea, but, because columbellinids lack the apertural sinuses characteristic of strombids and aporrhaiids, we concur with Fischer (1884) and Taylor et al. (1980) and include Columbellinidae in the Tonnacea. It is the earliest of the tonnacean families to appear; Taylor et al. (1980, p. 385) derive it from the Strombacea within the Jurassic. The tonnacean families Cymatiidae, Bursidae, and Cassididae are reported from the mid Cretaceous (Taylor et al., 1980, p. 387), but described forms are not compellingly similar to perissityids, and the similarity of some perissityids to cymatiids results from ancestry within the same family. The characteristics of perissityids are in many respects intermediate between those of columbellinids and buccinaceans.

Ponder (1973) argues that the neogastropods are derived from the Subulitacea rather than from the advanced tonnacean mesogastropods considered ancestral by Wenz (1938, p. 65; 1941, p. 1082) and others. Subulitaceans have, in the Paleozoic, already lost the median sinus of the outer lip (Ponder, 1973, p. 302), whereas early perissityids and volutes have a shallow notch which may be a posteriorly displaced remnant of the median sinus. Taylor et al. (1980, p. 385–386) suggest that instead of Subulitidae, the Purpurinidae are antecedent to neogastropods. The perrissityids, however, appear to be derived from a columbellinid ancestor, probably

in advance of the cymatiids, and perhaps in consort with Tudiclidae and Colubrariidae. These latter two families have been variously classified but are probable Buccinacea (Sohl, 1964; Ponder, 1973). The perrissityids, thus, suggest derivation of buccinaceans from early tonnaceans.

ORDER

Cox (1960) considered the line between mesogastropods and neogastropods to be arbitrary and included both orders in Caenogastropoda, but Ponder (1973) separates mesogastropods and neogastropods. Much of the evidence for separation lies in the soft parts and includes differences in chromosome numbers (Patterson, 1969; Ponder, 1973, p. 296), whereas similarities of neogastropods and some mesogastropods (tonnaceans) are evident in the shell. Both the soft and hard part comparisons involve interpretations as to derivation of structures, possible parallel evolution, etc. Unfortunately, for most soft part evolution there is no geologic record, and parallel and diverging evolution of shell form make the geologic record of the hard parts difficult to interpret. Neither Ponder's anatomical nor conchological criteria can be used for separation of fossil mesogastropod cymatiids and bursids from neogastropod buccinaceans. The fossil record suggests that perrissityids evolved during the Late Cretaceous from forms that resembled some cymatiid mesogastropods into forms that resemble some buccinacean and turrid neogastropods. The line between meso- and neogastropods is, of course, arbitrary, as it is drawn across evolving lineages irrespective of whether neogastropods derive from "primitive" or "advanced" mesogastropods. In shell form the perissityids appear transitional between Mesogastropoda and Neogastropoda, but in a hierarchical classification there is no place for transitional forms, and we include them in the Neogastropoda. The evolution of the Perissityidae suggests that most (perhaps all) neogastropods are derived from within the Columbellinidae, and that the superfamilies and families of the Neogastropoda arose both from different columbellinids and sequentially from columbellinid stocks.

SYSTEMATIC PALEONTOLOGY

Phylum Mollusca Linnaeus, 1758

Class Gastropoda Cuvier, 1797

Order Neogastropoda Wenz, 1938

Superfamily Buccinaceae Rafinesque, 1815

Family Perissityidae new family

DIAGNOSIS. Bucciniform gastropods with two folds or pseudofolds on the columella, a parietal welt or denticulations near the posterior end of the aperture, a posterior sinus to the growth line, and strong median denticulations within the outer lip. The outer lip flares anteriorly and is thickened by a varix. Impressions of former outer-lip thickenings and denticulations are found on steinkerns, even though such varices may not be obvious on the shell exterior.

The new family Perissityidae is proposed for several genera of gastropods that range from Late Cretaceous through Early Tertiary. The early Senonian species of these genera are of moderate size and bucciniform shape, with fine to coarse spiral ribs and short but strong axial ribs about the whorl periphery. All forms thus far studied have fairly large paucispiral protoconchs. The growth line has a shallow antispiral sinus adapical to the mid whorl. The outer lip is slightly thickened, rimmed, and flared, especially from mid whorl to the anterior siphonal constriction. The anterior sinus is nearly two-thirds as long as the eye-shaped aperture. The apertural armature, which is very characteristic in early Senonian forms, is ontogenetically intermittently developed and best displayed in the adult stage. Impressions of the typical outer lip denticles are found on natural casts, spaced as though indicating varices. Most characteristic is the strong denticle at mid whorl with commonly a lesser one anterior to it. This set of denticles is just anterior to the anterior end of the antispiral sinus and at the posterior end of the outer lip flare. The denticles oppose a pseudofold or fold on the columella. A moderately strong tubercle (or set of tubercles) in conjunction with similar tubercular structures on the inner lip constricts the posterior end of the aperture. Additionally there are usually small tubercles on the outer lip adjacent to the anterior siphonal canal. The inner lip is clearly demarked, fairly thick, and in some species forms a pseudoumbilicus at the anterior end of the anterior siphon with the siphonal fasciole. Medially on the columella there are two or three subequal pseudofolds or one or two folds.

Folds and pseudofolds do not differ in apertural view; both appear to be spirally elongate plicae on the columella. Folds spiral uninterrupted on the columella of the teleoconch (Figures 149, 152, 163), but pseudofolds are short, extending less than a quarter turn (Figure 20) into the shell anterior and are absent within earlier whorls (Figures 31, 117). Pseudofolds, like varices, are developed at growth halts, and shells that have not developed a thickened and denticulate outer lip do not show pseudofolds (Figures 17, 35), but folds are present even though the outer lip has not been thickened (Figure 170). The strongest folds occur, however, within apertures that have a well-developed varix, and folds are apparently enhanced by additional callus at growth halts.

Turonian and early Senonian perissityids resemble Columbellinidae in overall shape, in having a well-armed aperture, and in the position of the posterior sinus on the outer lip just adapical to the whorl periphery. The posterior sinus of perissityids is not as narrow and elongate as that of the columbellinids; later Senonian *Perissitys* spp. and *Christitys* spp. are of more pyriform shape than are columbellinids; and the anterior segment of the outer lip of perissityids flares.

Although many perissityids have varices, none has the regular varices of the Cymatacea. The range of shape in perissityids is similar to that in cymatiids, but cymatiids lack folds on the columella and do not cover the shell with callus.

Perissityidae, especially Turonian and early Senonian Perissityidae, resemble some members of the large and polymorphic family Buccinidae in shell shape, sculpture, and shape of aperture. Buccinids do not cover the shell with

callus, lack columellar folds, and do not have strong medial outer lip denticulations and an anteriorly flared outer lip.

Like Fasciolariidae, some perissityids have columellar folds, and some later Senonian perissityids develop a fusiform shape and/or a long anterior siphonal canal. Unlike fasciolariids some perissityids become strongly pyriform in shape and deposit callus over the shell.

Perissityids have been included in the Vasidae which some of them resemble in being pyriform and having folds on the columella. Perissityids do not have spinose sculpture, have an anteriorly expanded outer lip, and a typical pattern of outer lip denticulations which includes a strong medial denticulation.

Tudiclidae differ from pyriform Perissityidae in having a round aperture and a columellar fold at the posterior end of the anterior canal.

The posterior growth-line sinus of some perissityids resembles that of some Turridae, but turrids lack apertural armaments, external callus deposits, and columellar folds.

GENERA INCLUDED. *Perissitys* Stewart, 1927 (including *Cophocara* Stewart, 1927), *Pseudocymia* new genus, *Murphitys* new genus, *Christitys* new genus, and *Pseudoperissitys* Nagao & Otatume, 1938. Probably *Heteroterma* Gabb, 1869, will prove to be a perissityid; possibly *Nekewis* Stewart, 1927, belongs here.

DISTRIBUTION. North Pacific (Japan, Sakhalin, Alaska Peninsula, British Columbia, Washington, Oregon, California, Baja California) and eastern South Pacific (Chile, New Zealand).

GEOLOGIC AGE. Late Cretaceous (Turonian) to Early Tertiary (mid Selandian and possibly into Oligocene).

Genus **Perissitys** Stewart, 1927

TYPE SPECIES. *Perissitys brevirostris* (Gabb, 1864), by original designation (Stewart, 1927, p. 426).

DIAGNOSIS. Bucciniform to pyriform gastropods of medium to moderately large size with a subangulate whorl periphery which is ornamented by fewer than five spiral ribs. The crossing of these spiral ribs by short axial ribs produces the characteristic noded periphery. The edge of the outer lip anterior to the periphery is fimbriated. With the exception of the geologically earliest species, *P. cretacea* (Cooper), all species have an expanded inner lip that is developed at growth halts and is the inner lip equivalent of a varix.

REMARKS. Stewart (1927) did not assign this genus to a family, and he mentioned only one other species, *Pyropsis hombroniana* (d'Orbigny) from the Quiriquina Formation of Chile (Wilckens, 1904, p. 213, pl. 18, figs. 8, 9), as possibly belonging to *Perissitys*. Plaster casts of specimens of this species sent to us by Dr. E. Perez d'A. of Chile have a rounded aperture indicating that *P. hombroniana* is not a *Perissitys*, nor can it be included in the Perissityidae. *Pyropsis* sp. indet. of Nagao (1939, p. 228, pl. 21, fig. 5-5b) from "Upper Ammonites bed" = Upper Yezo Group, Abeshinai-gawa, Teshio Pref., Japan, is probably a *Perissitys*.

Morphologic changes which develop in West Coast *Perissitys* of Coniacian through Danian age include shortening of the spire and lengthening of the anterior canal so that the shell shape changes from bucciniform to pyriform, expansion of the inner lip over the apertural face and envelopment of the spire and most of the body whorl in a callus coat, and reduction and disappearance of pseudofolds from the columella and tubercles from the outer lip. The change from bucciniform to pyriform shape includes displacement of the noded periphery from mid whorl toward the base of the whorl. The rows of nodes on the periphery become reduced in prominence, although the number of rows of nodes initially increases and then decreases.

Coniacian *Perissitys, P. cretacea* (Cooper, 1896) resembles other Coniacian perissityids, but typical *Perissitys, P. brevirostris* (Gabb, 1864), differs from all other perissityid genera in having the inner lip expanded over the apertural face and spire of the shell. In pyriform shape *Perissitys* resembles *Tudicula* H. & A. Adams, 1863, *Tudiclana* Finlay & Marwick, 1937, *Tudicla* Röding, 1798, and *Pyropsis* Conrad, 1860. But none of these has the inner lip expanded onto the spire as in *Perissitys*. Except for *Tudiclana* all have an aperture posteriorly broadened resulting in a rounder aperture, and an inner lip which is folded onto the whorl. *Tudiclana* has a low fold at the base of the columella, and lacks the callus coat and the raised subsutural welt of *Perissitys*.

RANGE. Along the west coast of North America *Perissitys* is found in sandstones of Coniacian (Late Cretaceous) to early Selandian (middle Paleocene) age. The species are discussed in chronologic order from earliest to latest.

Perissitys cretacea (Cooper, 1896)

Figures 7, 16–26

Sistrum (*Ricinula*?) *cretaceum* Cooper, 1896, p. 330, pl. 47, figs. 1, 2; Coan, 1981, p. 161.

DIAGNOSIS. Bucciniform *Perissitys* with two strong spiral ribs about the periphery, the inner lip not markedly expanded, two pseudofolds on the columella, and denticles on the outer lip.

DESCRIPTION. Shell of medium size, bucciniform and thick walled; spire about one-third of total shell height, consisting of five or six whorls including a smooth, mammillate protoconch of nearly three whorls succeeded abruptly by a whorl strongly sculptured by raised spiral threads and axial ribs; next and succeeding whorls gently concave below the appressed suture, with strong double angulation about the mid whorl accentuated by two strong spirals crossing short strong axial ribs; last whorl concave below the median angulation, narrowing to form a sturdy anterior siphonal canal of moderate length, which is twisted to the left (apertural view) and backward at its tip; suture at the abapical peripheral angulation.

Sculpture above the peripheral angulation of eight to ten subequal spiral threads which on the last whorl are narrower than the interspaces; peripheral angulation accentuated by two strong spiral ribs which form nodes across 12–14 short but strong axial ribs; spiral ribs abapical to periphery slightly stronger than on ramp, strongest on whorl base, becoming finer toward anterior siphon.

Outer lip with shallow antispiral sinus adapical to the periphery and slight spiral antisinus abapical to the periphery; flaring moderately, flare thickened with callus deposit which continues around the posterior end of the aperture and rounds into the sharply demarked inner lip; inner lip of nearly equal width from posterior to anterior end of aperture, forming a pseudoumbilicus along the anterior siphonal canal at the siphonal fasciole. Outer lip with one strong, medial denticle interior to the periphery, a moderate denticle or denticle pair adapical to the strong dentiele, and a group of small denticles next to the anterior canal. Inner lip and columella with two nearly equal pseudofolds, the more adapical one opposite the strong denticle of the outer lip and a moderately strong denticle just abapical to the posterior end of the aperture.

NEOTYPE. UCLA 59588, here designated. Cooper (1896, p. 330) stated that he had four specimens, but Coan (1981, p. 161) was unable to find any of them.

HYPOTYPES. UCLA 59589–59594 from UCLA loc. 4104; UCLA 59601 from UCLA loc. 5990.

DIMENSIONS. Of neotype: UCLA 59588—height 30.5 mm (incomplete), diameter 19.9 mm, height of spire 11.2 mm; of hypotypes: UCLA 59590—height 19.4 mm (incomplete), diameter 13.8 mm, height of spire 6.7 mm; UCLA 59592—height 27.8 mm, diameter 17 mm, height of spire 9.9 mm; UCLA 59601—height 21.4 mm, diameter 14.1 mm (incomplete), height of spire 8.7 mm.

TYPE LOCALITY. Cooper (1896, p. 330) indicated only Morley, Shasta County, California, and the precise locality for his specimens is indeterminable. Morley School is shown in sec. 25, T33N, R2W, Millville Quadrangle (U.S.G.S., 1954), on the Oak Run Road more than 4 mi. northeast of UCLA loc. 4104 in sec. 16, T32N, R2W, Millville Quadrangle, Shasta Co., California. No outcrops yielding gastropods similar to *P. cretacea* have been found in the immediate vicinity of "Morley School," and Cooper's specimens may have come from the vicinity of UCLA loc. 4104.

DISTRIBUTION. Sandy beds of Member IV (Popenoe, 1943), CIT locs. 1007, 1289, and 1596, and UCLA locs. 4104 (= CIT loe. 1034) and 5990, Redding area, Shasta Co., California.

GEOLOGIC AGE. Coniacian.

REMARKS. None of Cooper's (1896, p. 330) four specimens is available (Coan, 1981), and it seems unlikely that Cooper's description and figures referred to any other species, but a neotype is designated to obviate confusion with other species of Perissityidae. His specimens probably came from outcrops of Member IV along Oak Run. More than 40 specimens are at hand, the largest of these, UCLA 59595 from UCLA loc. 4104, has a diameter of 21.2 mm. All specimens upon which the above description is based are from Redding area outcrops in Swede Basin, Oak Run, and Clover Creek, Millville Quadrangle, and along Old Cow Creek, Pine Timber Gulch, and Bear Creek, Whitmore Quadrangle (area 11). The species has not yet been recognized elsewhere; it is the earliest known of the inferred *Perissitys* lineage. It may possibly be derived from a Turonian form of the Redding area, *Pseudocymia aurora* new genus and new species, from the Frazier Siltstone below *Collignoniceras* sp. (Jones, et al., 1978, p. XXII.8).

Progressive changes within *P. cretacea* include shortening and broadening of the spire and adapical movement of the suture from anterior to the abapical strong peripheral rib to just covering this rib. The inner lip becomes slightly broader, especially on the body whorl, its outer edge becomes straighter, loses the angular bend, and rounds convexly to join the outer lip. The adapical edge of the inner lip moves from just touching the abapical strong peripheral rib to touching or covering the adapical strong peripheral rib. These are small changes, but the time period is apparently short.

Perissitys cretacea differs from *Pseudocymia aurora* in having its suture upon, rather than abapical to, the peripheral angulation, finer spiral ribs, a more contracted and concave base, a longer more twisted siphonal canal, and fewer denticulations on the outer lip. *P. cretacea* differs from all later species of the genus in having an inner lip callus which is of nearly equal width from posterior to anterior end of the aperture. The shape of *P. cretacea* is similar to that of *Cantharus occidentalis* (Gabb, 1864) of Cenomanian age (Murphy and Rodda, 1960, p. 845), but *C. occidentalis* lacks the pseudofolds and strong denticulations on the outer lip of *P. cretacea*. *C. occidentalis* resembles *P. cretacea* in having a flaring outer lip rather than the unflared lip of modern *Cantharus*.

Perissitys elaphia new species

Figures 27–41

DIAGNOSIS. Pyriform *Perissitys* with three to four strong spiral ribs about the periphery, an inner lip expanded to cover the apertural face of the last whorl, two columellar pseudofolds, and denticles along the outer lip.

DESCRIPTION. Shell of medium size, pyriform; spire about one-fourth of the height of the shell, comprised of 1.5 to 2 smooth, globose nuclear whorls, succeeded by two gently concave whorls, about twice as wide as high; last whorl three-fourths or more of the shell height, having a narrow tumid band just below the suture, a concave ramp and rounded periphery accentuated by three or four strong spiral ribs, and contracting abruptly abapically to form anterior siphonal canal; anterior siphonal canal about as long as the eye-shaped aperture, curving gently to the left (apertural view); suture at or just below the adapical strong spiral rib.

Sculpture on subsutural welt of fine spiral threads, on ramp of very fine distant spiral threads; strong ribs of periphery made nodular by 11–14 strong short axial ribs, interspaces of strong ribs having fine threads; base of whorl with three to five narrow riblets grading into threads and very fine threads on the anterior siphonal neck.

Outer lip with slight antispiral sinus adapical to the periphery and slight spiral antisinus at the periphery; flaring slightly especially at, and abapical to, the periphery, lip flare thickened with callus deposit that also fills the antispiral sinus and continues up onto the spire at the posterior end of the aperture, inner lip expanded posteriorly, overlapping the suture, then spreading roundly to cover the apertural face of the last whorl, curving at the most abapical strong rib back toward the anterior end of the siphonal canal and crossing at the siphonal fasciole to form a pseudoumbilical chink;

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edge of expanded inner lip well demarked. Outer lip with a strong median denticle interior to the adapical strong peripheral rib flanked by a moderately strong denticle on either side, and next to the anterior canal a group of small denticles. Inner lip and columella with two nearly equal pseudofolds, the more adapical one opposite the strong denticles of the outer lip and a moderately strong denticle just abapieal to the posterior end of the aperture.

HOLOTYPE. UCLA 59606 from CIT loc. 1232.

PARATYPES. UCLA 59607–59608 from CIT loc. 1232, 59609–59610 from UCLA loc. 3298, 59612–59613 from CIT loc. 1227, 59614–59615 from CIT 1246; 59618 from UCLA loc. 4107; 59620 from UCLA loc. 3623; 59621–59622 from CIT loc. 1016, 59623–59624 from UCLA loc. 3624; 59633–59634 from CIT loc. 1017.

HYPOTYPES. UCLA 59638 from UCLA loc. 3633; 59639 from UCLA loc. 4217; CAS 31325.01 from CAS loc. 31325.

DIMENSIONS. Of holotype—height 31.4 mm, diameter 19.7 mm, height of spire 8.4 mm; of paratypes—UCLA 59609, height 31.2 mm (incomplete), diameter 20.7 mm, height of spire 7.8 mm; 59633, height 26.5 mm (incomplete), diameter 17.6 mm, height of spire 7.9 mm.

TYPE LOCALITY. CIT loc. 1232: Price Hollow, 2250 ft. N, 2000 ft. E of SW cor. sec. 2, T32N, R2W, Millville Quadrangle, Shasta Co., California.

DISTRIBUTION. Member V and lower Member VI in Oak Run, Price Hollow, and Clover Creek of the Redding area (area 11); Chico Formation on Antelope Creek (area 2); Kingsley Cave Member of Chico Formation on Mill Creek (area 2); Musty Buck Member on Chico Creek (area 5) from approximately 360 m to 600 m above the base of the Chico Formation; lower Forbes Formation on Buckeye Creek (area 21); lower *Bostrychoceras elongatum* Zone of the Haslam Formation on Elkhorn Creek (area 3) and Browns River (area 4).

GEOLOGIC AGE. Santonian.

REMARKS. More than 100 specimens are assigned to this species. The largest of these, UCLA 59609 from UCLA loc. 3298, has a diameter of 20.0 mm. Geologically older specimens have rounder whorls (Figures 32, 36, 38), later ones have a longer, more concave ramp, narrower, more angulate peripheral swelling, and the parietal callus expanding farther up onto and around the spire (Figures 40, 41). A specimen (CAS 31325.01) from CAS loc. 31325 on Buckeye Creek in the Rumsey Hills (area 21) resembles those from UCLA loc. 3633 on Chico Creek (area 5), but it is more abruptly constricted abapical to the periphery, and has only the more abapical of the two pseudofolds on the columella. Specimens from UCLA loc. 3633 are not large. None has denticles on its outer lip, but two low pseudofolds are present on the columella. The absence of *Bostrychoceras elongatum* and *Inoceramus schmidti* from the Chico Creek section above this locality but below the earliest occurrence of *Baculites chicoensis* has led to the inference that the late Santonian is missing from the Chico Creek section (Ward et al., 1983; Haggart and Ward, 1984; Haggart, 1984). The specimen from Buckhorn Creek is from the lower Forbes Formation, and, if *B. elongatum* and *I. schmidti* Zone equivalents are missing from the Chico Creek section (Figure 2), it may be younger than those from UCLA loc. 3633 at which *Baculites capensis* is present.

The relative stratigraphic positions of *P. elaphia* and *P. brevirostris* are the same in the Chico Formation (area 5) and in the Nanaimo Basin (area 3). In the Nanaimo Basin *P. elaphia* occurs in the lower *B. elongatum* Zone and *P. brevirostris* occurs in the overlying *I. schmidti* Zone with *Canadoceras yokoyamai;* on Chico Creek *P. elaphia* occurs in the *Baculites capensis* Zone and *P. brevirostris* in the overlying *B. chicoensis* Zone with *Canadoceras yokoyamai.* On Mill Creek (area 2), *P. elaphia* occurs in the *I. schmidti* Zone of the Kingsley Cave Member. These *P. elaphia* from the *I. schmidti* Zone on Mill Creek and the *B. elongatum* Zone of the Nanaimo Basin resemble the *P. elaphia* of the upper *B. capensis* Zone on Chico Creek. *Inoceramus schmidti* and *C.*

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Figures 16–61. Three species of *Perissitys: P. cretacea* (Cooper), *P. elaphia* new species, and *P. brevirostris* (Gabb). All figures ×1 unless otherwise noted. Photos **19–23, 26–32, 35–36, 38, 40, 41, 48–50, 60, 61** by T. Susuki. As nearly as possible the figures are arranged from geologically oldest to youngest. **Figures 16–26,** *P. cretacea* (Cooper, 1896), Coniacian, **16–25,** hypotypes; **16, 18,** specimen with protoconch preserved, UCLA 59601 from UCLA loc. 5990, ×1.5; **17,** young individual with unadorned aperture, UCLA 59494 from UCLA loc. 4104, ×1.5; **19,** UCLA 59589 from UCLA loc. 4104; **20,** specimen having aperture cut away to show pseudofolds evanescing apically, UCLA 59593 from UCLA loc. 4104, ×1.5; **21, 23,** UCLA 59590 from UCLA loc. 4104, ×2; **22, 26,** UCLA 59592 from UCLA loc. 4104; **24,** varix on ablabral side of shell, UCLA 59591 from UCLA loc. 4104; **25,** neotype, UCLA 59588 from UCLA loc. 4104. **Figures 27–41,** *Perissitys elaphia* new species, Santonian; **27–29,** holotype, UCLA 59606 from CIT loc. 1232; **30,** paratype, UCLA 59612 from CIT loc. 1227, ×1.5; **31,** specimen cut to show pseudofolds at aperture and smooth columella of earlier whorls, paratype, UCLA 59607 from CIT loc. 1232; **32,** paratype, UCLA 59614 from CIT loc. 1246, ×1.5; **33,** ablabral view showing inner lip margin—compare to Figures 24 and 43, paratype, UCLA 59633 from CIT loc. 1017; **34,** paratype, UCLA 59621 from CIT loc. 1016; **35,** juvenile, paratype, UCLA 59614 from CIT loc. 1246, ×3; **36, 38,** paratype, UCLA 59609 from UCLA loc. 3298; **37,** paratype, UCLA 59623 from UCLA loc. 3624; **39,** paratype, UCLA 59621 from CIT loc. 1016; **40, 41,** hypotype, UCLA 59639 from UCLA loc. 4217. **Figures 42–61,** *Perissitys brevirostris* (Gabb, 1864), hypotypes; **42, 44,** early Campanian, juvenile with complete anterior canal, UCLA 59649 from UCLA loc. 3637, ×1.5; **43,** typical earliest Campanian profile resembling that of *P. elaphia,* UCLA 59648 from UCLA loc. 3637; **45–47,** specimen figured by Stanton, 1896, USNM 21254 from near Pentz; **48–50,** UCBMP 11069 from near Pentz; **51–53,** LACMIP 7247 from UCLA loc. 3641; **54, 56,** LACMIP 7248 from UCLA loc. 3643; **55, 59, 60,** UCLA 59661 from CIT loc. 1400, **60,** ×2; **57, 58,** topotype, UCLA 59666, from UCLA loc. 4082; **61,** mid Campanian form intermediate to *P. pacifica,* UCLA 28715 from CIT loc. 1158.

yokoyamai from the Dobbins Shale on Sand Creek (area 21) are below Chron 33r and of Santonian age (Ward et al., 1983); but in the Nanaimo Basin they occur with *P. brevirostris* and are undoubtedly of Campanian age. Early *P. brevirostris* occurs with *Baculites chicoensis* and *C. yokoyamai* within the early Campanian Chron 33r on Chico Creek (area 5); on Mill and Antelope creeks (area 2) *P. elaphia* similar to those of the *Baculites capensis* Zone on Chico Creek occurs in the *I. schmidti* Zone. Although *I. schmidti* Michael, 1899, has not yet been recognized in the Chico Creek section, other species that occur with it of both late Santonian and early Campanian age are present there, and the absence of *I. schmidti* is more probably a result of deposition in shallow water rather than indicative of a hiatus in the section.

If the late Santonian zones of *Bostrychoceras elongatum* and *Inoceramus schmidti* are missing from the Chico Creek section the evolution of *P. elaphia* must be more rapid in the early Santonian and slower in the late Santonian. *I. schmidti,* however, ranges from late Santonian through early Campanian (Haggart, 1984); its absence in the Chico Creek section may be related to ecologic factors rather than complete absence of strata of appropriate age, and the morphologic changes in *P. elaphia* were developed through the entire Santonian.

This species differs from *P. cretacea* in its more pyriform shape, expanded inner lip callus which covers the apertural face of the last whorl, and in typically having three denticles at the periphery on the outer lip. Although the growth line on the whorl has an antispiral sinus similar to that of *P. cretacea,* the edge of the outer lip is straightened by callus adapical to the periphery and the outer lip of *P. elaphia* has a straighter profile than that of *P. cretacea. P. elaphia* differs from *P. brevirostris* in having a weaker sutural welt which is not noded, denticulations in the aperture, and a more bent siphonal canal.

Pyropsis sp. indet. (Nagao, 1939, p. 228, pl. 2, figs. 5, 5a-b) is similar in shape to *Perissitys elaphia,* and the growth line description is similar, but no columellar pseudofolds or outer lip denticulations are mentioned. The specimen is small and "imperfect" (Nagao, 1939, p. 228) and may not yet have formed the characteristic structures. *Pyropsis* sp. indet. is probably a *Perissitys* new species; it is said to have about ten peripheral nodes whereas *Perissitys elaphia* has 11 to 14.

ETYMOLOGY. *Elaphos,* Greek, deer or stag, for its occurrence in the Musty Buck Member of the Chico Formation.

Perissitys brevirostris (Gabb, 1864)

Figures 10, 11, 42–61

Perissolax brevirostris Gabb, 1864, p. 91, pl. 18, fig. 43; Tryon, 1881, p. 104, pl. 30, fig. 67; Stanton, 1896, p. 1047, pl. 67, fig. 4; Whiteaves, 1903, p. 356, pl. 43, fig. 3; Arnold, 1909, p. 104, pl. 1, fig. 2; Grabau and Shimer, 1909, p. 769, fig. 1119; Arnold and Anderson, 1910, p. 274, pl. 23, fig. 2.

Tudicla (*Perissolax*) *brevirostris* (Gabb): Tryon, 1883, p. 141, pl. 51, fig. 59.

Tudicula (*Perissolax*) *brevirostris* (Gabb): Cossmann, 1901, p. 71, text-fig. 21.

Perissitys brevirostris (Gabb): Stewart, 1927, p. 426, pl. 20, fig. 4; Schenck and Keen, 1940, pl. 17, fig. 5; Popenoe, 1954, p. 17, fig. 4(5); Popenoe, 1973, p. 20, pl. 2, fig. 16; Saul and Alderson, 1981, p. 36, pl. 3, fig. 5.

Tudicla (*Perissitys*) *brevirostris* (Gabb): Wenz, 1943, p. 1304, abb. 3718.

Not *Perissitys brevirostris* (Gabb): Sundberg and Riney, 1984, p. 105, fig. 3.3 = *Murphitys madonna* new species.

DIAGNOSIS. Pyriform *Perissitys* with three strong spiral ribs about the periphery, a noded subsutural welt, inner lip expanded to cover all of the apertural face of the shell, and no apertural ornaments.

DESCRIPTION. Shell of medium to moderately large size, pyriform; spire about one-fifth of the height of the shell, comprised of 1.5 to 2 smooth, globose nuclear whorls, succeeded by 2–4 gently concave whorls, nearly three times as wide as high; last whorl about half of the shell height, having a noded, tumid band just below the suture, a concave ramp, a rounded periphery accentuated by three strong spiral ribs, and contracting abruptly to form anterior siphonal canal; anterior siphonal canal at least as long as the eye-shaped aperture, curving slightly to the left (apertural view); suture at the adapical strong rib.

Sculpture on noded subsutural welt of fine spiral threads, on margin of ramp of very fine distant spiral threads, mid ramp nearly smooth; strong ribs of periphery subequal, two adapical ribs equal and stronger, third (abapical) rib closer to second rib than second is to first; ribs made nodular by about 13 strong short axial ribs, interspaces of strong spiral ribs having fine threads; base of whorl with about four riblets; siphonal neck with faint distant spiral threads.

Outer lip nearly straight, with slight antispiral sinus and spiral antisinus, barely thickened; inner lip callus expanding up onto spire and covering most of apertural face of shell and lapping onto abapertural surface of siphonal neck. Aperture without denticles or pseudofolds.

HOLOTYPE. ANSP 4188 (Stewart, 1927, p. 426).

HYPOTYPES. USNM 21254 and UCBMP 11069 from near Pentz, Butte Co. (area 5); CGS 5792 from Sucia Island, Washington (area 18); UCLA 28715 from CIT loc. 1158, Bell Canyon (area 17), 59648–59649 from UCLA loc. 3637, Chico Creek (area 5), 59661 from CIT loc. 1400, Sucia Island (area 18), and 59666 from UCLA 4082, Tuscan Springs (area 2); LACMIP 7247 from UCLA loc. 3641, and 7248 from UCLA loc. 3643, both Chico Creek (area 5).

DIMENSIONS. Of hypotypes—UCBMP 11609, height 47 mm, diameter 30.3 mm, height of spire 10 mm; LACMIP 7247, height 33.7 mm, diameter 20.4 mm, height of spire 6 mm; LACMIP 7248, height 40 mm, diameter 27.2 mm, height of spire 8.6 mm; UCLA 59661, height 22 mm (incomplete), diameter 17.3 mm, height of spire 6 mm; UCLA 28715, height 41.5 mm, diameter 30.8 mm, height of spire 9.8 mm.

TYPE LOCALITY. Tuscan Springs, Tehama Co., California (area 2).

DISTRIBUTION. Chico Formation at Tuscan Springs (area 2); associated with *Submortoniceras chicoense* (Trask) in the Ten Mile Member, Chico Formation on Chico Creek and Butte Creek (area 5), and the Chico Formation at Pentz Ranch (area 5); upper Holz Shale Member of the Ladd Formation, Santa Ana Mountains (area 13); found below and with *Hoplitoplacenticeras vancouverense* (Meek) in the Cedar District Formation on Sucia Island (area 18); and in the upper *Inoceramus schmidti* Zone of the Haslam Formation at Blunden Point, on Brannan Creek, and the north shore of Departure Bay (area 3). Specimens from the lower Chatsworth Formation in Bell Canyon (area 17) are intermediate between *P. brevirostris* and *P. pacifica.*

GEOLOGIC AGE. Early and mid Campanian.

REMARKS. This is the most abundantly represented and most widely distributed species of *Perissitys.* The largest of the more than 100 specimens at hand is UCLA 59658 from UCLA loc. 3647, which despite lacking most of the shell on the last whorl, has a diameter of 44.6 mm. *Pyropsis* sp. indet. of Nagao (1939, p. 228, pl. 21, fig. 5-5b), which is of Coniacian or Santonian age (Hayami and Kase, 1977, p. 65), appears similar in shape to *P. brevirostris,* but, except that the inner lip is said to be expanded, the aperture is not described. The Alaskan specimens from the Chignik Formation listed as *Perissolax brevirostris* Gabb by Martin (1926, p. 304) are neither *brevirostris* nor *Perissitys.* Although they have a pyriform shape similar to *P. brevirostris,* they have a fold on the columella and other apertural denticulations, and they lack the widely expanded inner lip of *P. brevirostris.* They are described as *Christitys martini* new species.

The cowl of callus in *P. brevirostris* is usually deposited at intervals and its development probably records the onset of resting or non-growth periods, and, as it can be seen on the spire (Figures 55, 59), it is an inner lip equivalent of a varix. There is no apparent regularity to these growth halts.

Perissitys brevirostris remains a recognized taxon through a longer time (6± Ma) than any other species of *Perissitys,* and its evolutionary changes are more subtle than those of its predecessor, *P. elaphia. P. brevirostris* differs from late *P. elaphia* in reaching a larger size, having the siphonal neck smoother and the subsutural welt more swollen and nodular, and in having a straighter anterior canal. The parietal lip is more expanded, but its margin is less distinct. No specimen assigned to *P. brevirostris* has denticulations or pseudofolds arming the aperture. In reducing apertural armaments Campanian *Perissitys* moves contrary to the apertural strengthening trend noted by Vermeij (1977), which he suggests helps to reduce shell breakage by arthropods. The enlargement of the callus to cover the apertural face may strengthen the shell, but it leaves the outer lip and at least half of the last whorl undefended. The callus becomes thicker and more enveloping in *P. pacifica. P. pacifica* and *P. brevirostris* are alike in providing the largest available specimens of *Perissitys.* In addition to the thicker callus, *P. pacifica* differs from *P. brevirostris* in having the three strong peripheral ribs closer together, the middle rib strongest and the abapical rib weakest, and in having a better developed posterior siphonal notch.

Specimens identified as *P.* cf. *P. brevirostris* (Figure 43) from the lower 100 m of the Ten Mile Member on Chico Creek (area 5) have a higher spire and more concave ramp than typical *P. brevirostris.* They are similar to the latest *P. elaphia* except for the apertural armaments. A specimen from UCLA loc. 3635, which is at the base of this interval, has a low pseudofold on the columella like that of the specimen (CAS 31325.01) from CAS loc. 31325, Buckeye Creek, Rumsey Hills (area 21). Specimens of *P.* cf. *P. brevirostris* from above the base of this 100-m interval have no pseudofolds.

Ammonites have not been found associated with *P. brevirostris* at its type locality at Tuscan Springs (area 2). The specimens of *P. brevirostris* from there resemble those from Pentz (area 5), where *Submortoniceras chicoense* is common and from the upper 500 m of the Chico Formation on Chico Creek (area 5). Outcrops of the Chatsworth Formation in Bell Canyon, Simi Hills (area 17), are believed (Saul and Alderson, 1981; Saul, 1983) to be older than the zone of *Metaplacenticeras pacificum. Perissitys* from Bell Canyon are intermediate between *P. brevirostris* and *P. pacifica* (Figure 61).

Perissitys pacifica new species

Figures 62–69

DIAGNOSIS. Pyriform *Perissitys* which have two strong and one weak spiral ribs about the periphery, a waved subsutural welt, the inner lip expanded to cover about half of the shell, and no apertural ornaments.

DESCRIPTION. Shell of medium to moderately large size, pyriform; spire about one-fifth of the height of the shell, comprised of 1.5 to 2 smooth, globose nuclear whorls, succeeded by 2–4 gently concave whorls more than three times as wide as high; last whorl about half of shell height, having a waved, tumid band adjacent to the suture, a concave ramp, and subangulate periphery accentuated by two strong and one weaker spiral ribs, contracting abruptly to form anterior siphonal canal; anterior siphonal canal slightly longer than the eye-shaped aperture, curving slightly to the left (apertural view) and abaperturally; suture at the adapical strong rib.

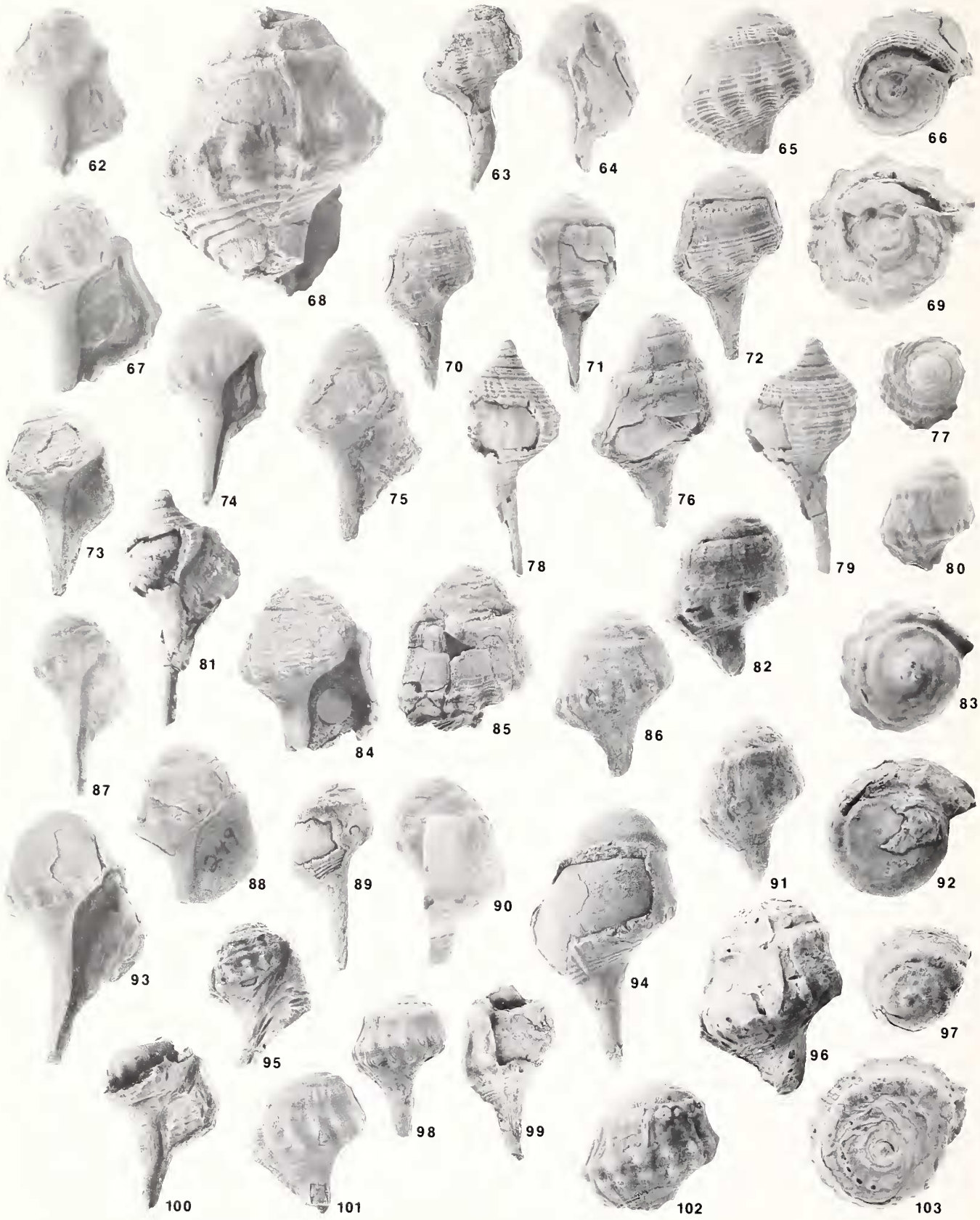
Sculpture on waved sutural welt of about five close-set spiral riblets, on ramp of distant spiral threads; peripheral spiral ribs made nodular by 12–13 strong, very short axial ribs, interspaces of peripheral spiral ribs having riblets; base of whorl with about four spiral riblets; siphonal neck with distant spiral threads.

Outer lip nearly straight with a slight posterior siphonal sinus at the sutural welt, a faint antispiral sinus and spiral antisinus at the periphery, edge thickened by callus which coats a narrow strip of the outside of the whorl, expands up over the spire, and covers the apertural face of the whorl. Aperture without denticles or pseudofolds.

HOLOTYPE. UCLA 59691.

PARATYPES. UCLA 59692 from CIT loc. 1159; 59696–59698 from CIT loc. 974; 59712 from UCLA loc. 4207; 59715 from UCLA loc. 2415; 59719 from UCLA loc. 7110.

DIMENSIONS. Of holotype—height 30.5 mm (incomplete), diameter 24.4 mm, height of spire 6.5 mm; of paratype—UCLA 59719, height 33.8 mm, diameter 19 mm (in-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complete), height of spire 5.5 mm; UCLA 59696—height 36.5 mm (incomplete), diameter 29.5 mm, height of spire 9 mm.

TYPE LOCALITY. CIT loc. 1159, Dayton Canyon, Simi Hills, Los Angeles Co., California (area 17).

DISTRIBUTION. Associated with *Metaplacenticeras* cf. *M. pacificum* (Smith) in the Pleasants Sandstone Member of the Williams Formation, Santa Ana Mountains (area 13); the Chatsworth Formation in Dayton Canyon, Simi Hills (area 17); and the Tuna Canyon Formation in the Santa Monica Mountains (area 16). Also collected from near the top of the Debris Dam Sandstone, Agua Caliente Canyon (area 1), and an unnamed formation on the Salsipuedes arm of Santa Margarita Lake (area 15).

GEOLOGIC AGE. Late Campanian, *Metaplacenticeras pacificum* Zone.

REMARKS. A greater length of anterior siphonal canal is present on the specimen (Figure 63) from Garapito Creek, Santa Monica Mountains (area 16) than on any of the other 50+ available specimens.

The largest specimen, UCLA 59715 from UCLA loc. 2415, has a diameter of 51.5 mm. *P. pacifica* is very similar to *P. brevirostris* in shape and sculpture. It has a shorter, more callus-covered spire; the peripheral ribs are closer together; the subsutural welt is waved rather than noded; and the posterior siphonal notch is better developed. Steinkerns of the two species can be distinguished even if most of the shell is missing; those of *P. brevirostris* have a roundly convex profile, whereas those of *P. pacifica* are flattened to slightly concave adapical to the more angulate periphery. Some specimens of *P. pacifica* have less prominent peripheral nodes and are closer to *P. colocara* than to *P. brevirostris*.

ETYMOLOGY. *Pacifica,* for its occurrence in the *Metaplacenticeras pacificum* Zone.

Perissitys colocara new species

Figures 70–86

Cophocara n.sp. Popenoe, 1973, p. 24, fig. 39; Saul and Alderson, 1981, p. 36, pl. 3, figs. 6, 7; Sundberg and Riney, 1984, p. 105, fig. 3.1.

DIAGNOSIS. Pyriform *Perissitys* which have two to three closely spaced spiral ribs about the periphery, a strong wrinkled subsutural welt, inner lip expanded to cover at least two-thirds of the shell, and no apertural ornaments.

DESCRIPTION. Shell of medium to moderately large size, pyriform; spire variable but usually less than one-fourth of height to shell, comprised of 2–3 globose, smooth nuclear whorls, succeeded by two convexly rounded whorls commonly four times as wide as high, followed by 1–2 barely concave whorls of similar height to width, all callus coated; last whorl constituting half of shell height, having a tumid band just below the suture, a slight concavity to the ramp profile adjacent to the tumid band, and broadly expanded, subangulate periphery accentuated by 2–3 spiral ribs, contracting abruptly to form anterior siphonal canal; anterior siphonal canal longer than the triangulate aperture; suture adapical to the peripheral ribs, just abapical to the slight concavity of the ramp.

Sculpture on sutural welt of 2–5 spiral riblets, on ramp of distant spiral threads; peripheral spiral ribs made nodular by 10–14, extremely short, axial ribs; base of whorl commonly with four fine spiral riblets; siphonal neck with distant fine spiral threads.

Outer lip with posterior siphonal notch at the sutural welt, a slight antispiral sinus just adapical to the periphery and spiral antisinus at the periphery, edge slightly thickened by callus which covers at least two-thirds of the shell. Aperture without denticles or pseudofolds.

HOLOTYPE. LACMIP 7249.

PARATYPES. UCLA 59082 from UCLA loc. 6534, 59217 from UCLA loc. 3814; LACMIP 7253–7254 from LACMIP loc. 7792, 7256 from UCLA loc. 3268, 7250–7252 from UCLA loc. 6534, 7255 from UCLA loc. 7149, and 7257 from LACMIP loc. 2852; UCBMP 37992 from UCB loc. A-6618, 37993 from UCB loc. B-5321; and CAS 463.01 from CAS loc. 463.

DIMENSIONS. Of holotype—LACMIP 7249, height 36.7 mm, diameter 19 mm, height of spire 8 mm; of paratypes—LACMIP 7250, height 38.4 mm, diameter 24.8 mm, height of spire 12.3 mm; UCLA 59082, height 23.8 mm, diameter 14.3 mm, height of spire 5.6 mm; LACMIP 7256, height

←

Figures 62–103. Four species of *Perissitys: P. pacifica* new species, *P. colocara* new species, *P. stantoni* (Stewart), and *P. stewarti* (Zinsmeister). All figures ×1 unless otherwise noted. Photos **72, 74–76, 84, 85, 88, 93, 94** by T. Susuki. As nearly as possible, the figures are arranged from geologically oldest to youngest. **Figures 62–69,** *P. pacifica* new species, late Campanian; **62, 64,** holotype, UCLA 59691 from CIT loc. 1159; **63,** paratype, UCLA 59719 from UCLA loc. 7110; **65, 66,** paratype, UCLA 59712 from UCLA loc. 4207, ×1.5; **67, 69,** paratype, UCLA 59696 from CIT loc. 974; **68,** paratype, UCLA 59715 from UCLA loc. 2415. **Figures 70–86,** *P. colocara* new species, early Maastrichtian; **70,** paratype, LACMIP 7252 from UCLA loc. 6534; **71, 74,** holotype, LACMIP 7249 from LACMIP loc. 7962; **72, 73,** paratype, UCLA 59082 from UCLA loe. 6534; **75, 76,** paratype, LACMIP 7250 from UCLA loc. 6534; **77,** juvenile with protoconch, paratype, LACMIP 7254 from LACMIP loc. 7792, ×4; **78, 79, 81,** juvenile with protoconch, paratype, LACMIP 7253 from LACMIP loc. 7792, ×2.5; **80, 83,** paratype, LACMIP 7255 from UCLA loc. 7149, **83,** ×1.5; **82,** paratype, CAS 463.01 from CAS loc. 463, ×1.5; **84, 85,** paratype, LACMIP 7256 from UCLA loc. 3268; **86,** hypotype, UCBMP 37992 from UCB loc. A-6618. **Figures 87–95,** *P. stantoni* (Stewart), hypotypes, late Maastrichtian; **87, 89,** LACMIP 7259 from CIT loc. 1602; **88,** UCBMP 37994 from UCB loc. 249; **90, 92,** USNM 400974 from USGS loc. 7059; **91,** UCBMP 37995 from UCB loc. A-3216; **93, 94,** LACMIP 7258 from CIT loc. 1602; **95,** LACMIP 7260 from UCLA loc. 1594. **Figures 96–103,** *P. stewarti* (Zinsmeister), hypotypes, early Paleocene; **96,** UCBMP 37996 from UCB loc. A-3262; **97, 101,** CAS 61617.01 from LSJU loc. 1068, ×1.5; **98, 103,** CAS 61619.01 from LSJU loc. 2245, **103,** ×1.5; **99, 100,** CAS 61616.01 from LSJU loc. 460; **102,** CAS 61616.02 from LSJU loc. 460.

31.2 mm (incomplete), diameter 25.4 mm, height of spire 9.7 mm; LACMIP 7255, height 20 mm (incomplete), diameter 17 mm, height of spire 5 mm; CAS 463.01, height 20.7 mm, diameter 16.5 mm, height of spire 4.8 mm.

TYPE LOCALITY. LACMIP loc. 7962, Carlsbad Research Park, San Diego Co., California (area 20).

DISTRIBUTION. Rosario Formation in Arroyo Santa Catarina (area 14), at Punta San Jose (area 10), near San Antonio del Mar (area 12), at Point Loma (area 9), and vicinity of Carlsbad (area 20); Chatsworth Formation on Lang Ranch, Simi Hills (area 17); upper Panoche Formation north of Coalinga, Fresno Co. (area 8); "Moreno Grande" Formation of Huey (1948) on Ortigalita Creek, Merced Co. (area 8).

GEOLOGIC AGE. Early Maastrichtian.

REMARKS. The greatest abundance of this species is from localities in Arroyo Santa Catarina (area 14), but specimens are also common at UCLA loc. 5902 north of Coalinga (area 8). Most are small, but a few medium-sized specimens are available and a large partial specimen from UCB loc. A-6618 has a diameter of 33.7 mm.

The sculpture on the sutural welt and the ramp is subdued, but the callus coating is applied so as to accentuate the spiral threads and riblets and *P. colocara* appears to have stronger spiral sculpture than does *P. pacifica.* On many specimens such a thick welt of parietal callus is applied at the growth pauses that the spiral curve of the shell is offset. The specimens look lumpy and distorted. *P. colocara* is unusually variable for this group in height of spire and peripheral ribbing. A few specimens have a spire height closer to one-third of the height of the shell (Figures 75, 76) rather than the more common under one-fourth proportion. Some specimens have peripheral ribs similar to those of *P. pacifica,* but most have finer ribs, more closely spaced, similar to those of *P. stantoni. P. colocara* is more callus coated than is *P. pacifica* and a little less so than *P. stantoni.* The subsutural welt of *P. colocara* is stronger than that of *P. pacifica,* is adapical to the peripheral nodes and less undulating than that of *P. pacifica.* The suture on adult *P. colocara* is more deeply channeled than it is on *P. pacifica* or *P. stantoni,* and the whorl of *P. colocara* is more angulate than is that of *P. stantoni.*

ETYMOLOGY. *Kolos,* Greek, docked, curtailed, shortened, stunted, and *kara,* Greek, head, top, referring to the usually short spire of the species.

Perissitys stantoni (Stewart, 1927)

Figures 87–95

Cophocara stantoni Stewart, 1927, p. 428, pl. 20, figs. 1–3; Saul, 1986, p. 27, fig. 21.

Tudicla (*Cophocara*) *stantoni* (Stewart): Wenz, 1943, p. 1305, fig. 3719.

Not *Cophocara stantoni* Stewart: Smith, 1975, p. 475, pl. 2, figs. 17, 18 = *P. stewarti* (Zinsmeister).

DIAGNOSIS. Pyriform *Perissitys* with one dominant spiral rib about the periphery, a weakly noded subsutural welt, the shell well coated with callus except for last quarter of last whorl, and apertural ornaments lacking.

DESCRIPTION. Shell of medium to moderately large size, pyriform; spire about one-fifth of height of shell, comprised of 3–4 post-nuclear whorls about four times as wide as high, all callus coated; last whorl about half of shell height, having a tumid band adjacent to the suture, a slight concavity to the ramp profile adjacent to the tumid band, and an expanded, subangulate periphery accentuated by 1–3 spiral ribs of which one is dominant; whorl contracting abapically abruptly to form anterior siphonal canal; anterior siphonal canal nearly as long as eye-shaped aperture; suture just abapical to the slight concavity of the ramp.

Sculpture nearly obliterated by callus coating except on last quarter of last whorl; sutural welt of large specimens slightly nodulose; perhipheral spiral ribs made nodular by 15–17 extremely short axial ribs; base of whorl with about three spiral riblets.

Outer lip with posterior siphonal notch at the sutural welt; growth line strongly bent at the posterior notch, otherwise straight; inner lip expanded to cover all but last quarter of last whorl. Aperture without denticles or pseudofolds.

HOLOTYPE. USNM 73399.

PARATYPES. USNM 73400 and 73403 from USGS loc. 1258; whereabouts of the ANSP specimen figured by Stewart (1927, pl. 20, fig. 2) from near Martinez, Contra Costa Co. (area 7), is unknown (Elana Banamy, *in litt.,* 17 Oct. 1985).

HYPOTYPES. USNM 400974 from USGS loc. 7059 (area 8); UCBMP 37994 from UCB loc. 249 (area 7) and 37995 from UCB loc. A-3216 (area 8); LACMIP 7258–7259 from CIT loc. 1602 (area 7), and 7260 from UCLA loc. 1594 (area 19).

DIMENSIONS. Of holotype—height 42.2 mm (incomplete), diameter 26 mm, height of spire 17.5 mm; of hypotypes—USNM 400974, height 34.6 mm (incomplete), diameter 27.4 mm, height of spire 7.5 mm; UCBMP (37994), height 30.5 mm (incomplete), diameter 24 mm, height of spire 8.7 mm; LACMIP 7258, height 47.3 mm, diameter 27 mm, height of spire 9 mm.

TYPE LOCALITY. USGS loc. 1258, near Blum and Company's Pacheco warehouse, 1½ mi. north of Pacheco, Contra Costa Co., California (area 7).

DISTRIBUTION. Near or at the top of the Great Valley Series in the vicinity of Martinez, Deer Valley, and Riggs Canyon (area 7); Garzas and Volta Sands near Pacheco Pass, Merced and Stanislaus cos. (area 8); Asuncion Formation on Cantinas Creek, southern Santa Lucia Range, San Luis Obispo Co. (area 15); basal San Francisquito Formation on Warm Springs Mountain (area 19).

GEOLOGIC AGE. Late Maastrichtian.

REMARKS. The type species of *Cophocara* Stewart, 1927, is *C. stantoni.* As the most notable difference between it and *Perissitys pacifica* is the thicker, more enveloping callus layer on *C. stantoni,* we include *stantoni* in *Perissitys. P. stantoni* has fewer and weaker spiral ribs, weaker nodes and thicker callus covering than any other described species of *Perissitys.* It is very similar to *P. colocara,* but has a less concave whorl profile abapical to the sutural welt and more rounded whorl profile abapical to the periphery, more and smaller nodes on the periphery, a more nodulose subsutural band, and better

developed posterior siphonal notch. Although a few speeimens of *P. colocara* are large, the average size of the 40+ specimens studied of *P. stantoni* is about twice that for specimens of *P. colocara,* and the largest specimen recorded was one of Gabb's, which was a diameter of 36 mm (Stewart, 1927, p. 428).

The specimens from UCLA loc. 1594 on Warm Springs Mountain are poorly preserved. They resemble *P. stantoni,* but may have had a more tumid subsutural welt and a spiral row of nodes on the ramp (Figure 95).

Perissitys stewarti (Zinsmeister, 1983)

Figures 96–103

Cophocara stantoni Stewart: Smith, 1975, p. 465, pl. 2, figs. 17, 18. Not *Cophocara stantoni* Stewart, 1927.

Cophocara stewarti Zinsmeister, 1983, p. 1298, fig. 3*J*; not fig. 3*K* = "*Heteroterma trochoidea* Gabb" of Nelson, 1925, non Gabb, 1869.

DIAGNOSIS. Pyriform *Perissitys* with two spiral ribs about the periphery, a nodulose subsutural welt, the inner lip expanded to cover nearly two-thirds of the shell, and no apertural ornaments.

HOLOTYPE. UCR 6670/9.

HYPOTYPES. CAS 61619.01 from LSJU loc. 2245, CAS 61616.01 and 61616.02 from LSJU loc. 460, and CAS 61617.01 from LSJU loc. 1068; UCBMP 37996 from UCB loc. A-3262.

DIMENSIONS. Of holotype—height 28 mm (incomplete), diameter 29 mm, height of spire 5 mm; of hypotypes—LSJU 10240, height 25.9 mm, diameter 19.3 mm, height of spire 4.3 mm; LSJU 10241, height 23 mm (incomplete), diameter 24.5 mm, height of spire 5.9 mm; CAS 61617.01, height 16.9 mm (incomplete), diameter 4 mm, height of spire 3 mm.

TYPE LOCALITY. UCR loc. 6670, Simi Hills, Ventura Co., California (area 17).

DISTRIBUTION. Lower Santa Susana Formation, Simi Hills (area 17) (Zinsmeister, 1983, p. 1298); near the base of the Laguna Seca Formation, Panoehe Hills, Fresno Co. (area 8) (Smith, 1975, p. 468); San Francisquito Formation on north side of East Fork Fish Canyon (UCLA loc. 1581) (area 19); Sepultura Formation at Punta Canoas (UCLA loc. 6368) (area 14).

GEOLOGIC AGE. Early Paleocene, late *Turritella peninsularis quaylei* (area 19) and *T. peninsularis* zones (area 17). Speeimens from near the base of the Laguna Seea Formation (area 8) may be older; they are probably below localities with *T. peninsularis,* but the available collections have no associated turritellas. Misidentified as *Cophocara stantoni, P. stewarti* has been used to indicate Cretaceous age. Some of the localities are recorded as being from the Moreno Formation, others as being from the Laguna Seca Formation. The formational name seems in some cases to have been chosen on a faunal rather than lithologic basis: Moreno, if the fossils were considered to indicate Cretaceous age, Laguna Seca (or equivalent), if a Paleocene age seemed indicated. Plotted on a map, the purported younger locality may appear to be downsection from the older, and stratigraphic range of *P. stewarti* cannot be inferred.

REMARKS. The spire makes up one-seventh to one-eighth of the height of the shell. Post-nuclear whorls are about six times as wide as high, and all are callus coated; about half of shell height is the last whorl. The two strong peripheral spirals are made nodose by 14–17 extremely short, axial ribs; and the base of the whorl has 4–5 spiral riblets adjacent to the siphonal neck. The growth line is strongly bent at the posterior notch but is otherwise straight. The aperture is without denticles or pseudofolds. The anterior canal is straight except for a backward bend near its tip.

P. stewarti is the youngest recognized *Perissitys.* It has the shortest spire of known species, and were its ancestry unknown, its classification in the Tudiclidae (Zinsmeister, 1983, p. 1298) would be apt. *P. stewarti* is very similar to, and easily confused with, *P. stantoni,* but has a thinner, less extensive callus, more strongly marked varices, a deeper posterior siphonal notch, and stronger nodes on the subsutural band. The peripheral nodes are in two nearly equal rows, whereas *P. stantoni* has one dominant row. The anterior siphonal canal is much shorter and has a stronger backward flexure near its tip. A virtually shell-less specimen from UCB loc. A-3262 has a diameter of 26.2 mm and, with shell, would be larger than the holotype.

Perissitys stewarti resembles *Heteroterma trochoidea* Gabb, 1869, in its two spiral rows of nodes and short spire, but *H. trochoidea* lacks the callus coating over the shell, the strong rounded welt at the suture, and has a more sloping ramp. *P. stewarti* resembles *H. gabbi* Stanton, 1896, in whorl profile, but *H. gabbi* lacks the callus coating and has longer axial ribs crossed by several spiral ribs. *H. striata* Stanton, 1896, lacks the sutural welt and the callus coating and has at least four spiral ribs about the periphery.

Genus *Pseudocymia* new genus

TYPE SPECIES. *Pseudocymia aurora* new species.

DIAGNOSIS. Small to medium sized, shortly fusiform gastropods with shouldered whorls having a concave ramp and base straightly sloping into an anterior siphonal neck of short to moderate length which is bent to the left and abaperturally, and has near its anterior end a well-developed siphonal fasciole. The shell appears to be out-of-round, a little flattened aperture-to-back and expanded laterally. It is ornamented by narrow spiral ribs which override strong, short axial ribs. The axial ribs are most pronounced on the periphery. The spire is less than half of the total shell height. The aperture is elongate oval with well-demarked inner lip and flaring outer lip. The inner lip has two pseudofolds near the base of the whorl and another near the posterior end of the aperture. The outer lip is thickened and denticulated with the strongest denticulations opposite the base of the whorl.

RANGE. Turonian to Maastrichtian.

DISCUSSION. This genus is based on *P. aurora* of Turonian age. It resembles species of *Columbellina* but lacks the marked, oblique posterior sinus in the outer lip. The outer

lip denticulations are, however, separated into posterior and medial sets by a groove similarly placed to that of *Columbellina*'s posterior sinus. *P. aurora* has a remarkable resemblance to *Cymia tecta* (Wood, 1828) of the modern Panamic fauna, but lacks the medial columellar fold of that species and is slightly compressed. The aperture-to-back flattening of the shells is suggestive of Cymatiidae and Bursidae. Another group in the Perissityidae which shares this characteristic is that of "*Fusus*" *kingii* Gabb. *Pseudocymia* is uniangulate about the periphery rather than distinctly biangulate as is the "*Fusus*" *kingii* group. *Pseudocymia* remains fusiform rather than becoming pyriform as do *Perissitys* and *Christitys*. It lacks the columellar folds of *Christitys* and *Murphitys*.

The genus is named for its resemblance to the type species of *Cymia, C. tecta* (Wood, 1828).

Pseudocymia aurora new species

Figures 104–108

DIAGNOSIS. Thick-shelled *Pseudocymia* with a broad apical angle and an outer lip that is considerably thickened and internally strongly lirate.

DESCRIPTION. Shell of medium size, broadly fusiform, rather massive, somewhat compressed aperture-to-back; spire of about four whorls, convex-conical in outline; apical angle approximately 60°; whorl outline subangular, shouldered just abapical to the middle, ramp gently concave; last whorl with a fairly broad, steeply sloping, slightly concave ramp adapical to the shoulder, abapical to which the whorl contracts evenly to the anterior end; suture linear, impressed, sinuous; siphonal fasciole well developed, rounded, enclosing a very shallow umbilical pit.

Spiral sculpture of the body whorl consisting of about 12 moderately strong revolving round-topped ridges below the whorl shoulder, and two or three much weaker spirals above the whorl shoulder, separated by interspaces somewhat wider than the spirals, and generally with two or three very fine revolving lirae in the interspaces; axial sculpture of about 12 blunt rounded ribs on the shoulder, obsolete or absent adapically and abapically.

Inner lip with a moderately thick callus coating, concave parietally, nearly straight anteriorly to the narrow and twisted canal, ornamented near the posterior suture with a pronounced rounded swelling bearing three or four transverse denticulations, and near its mid-length by two low rather distantly placed pseudofolds of which the posterior is slightly stronger; outer lip much thickened and bearing internally a series of strong transverse wrinkles which increase in size progressively from anterior end to whorl shoulder; outer lip rather deeply notched internally opposite the whorl shoulder, posterior to which two smaller wrinkles oppose the swelling on the inner lip and enclose adapically a narrow anal gutter at the juncture of the lips.

HOLOTYPE. UCLA 59586.

PARATYPE. UCLA 59587 from CIT loc. 1532, Salt Creek, Millville Quadrangle (area 11).

DIMENSIONS. Of holotype—height 37.5 mm; height of last whorl 25 mm; diameter 23.5 mm; height of spire 14.4 mm.

TYPE LOCALITY. CIT loc. 1212, Salt Creek, Millville Quadrangle, Shasta Co., California (area 11).

DISTRIBUTION. Represented by two specimens, both from the upper half of the Frazier Silt on Salt Creek, Shasta Co., California.

GEOLOGIC AGE. Late Turonian, horizon of *Subprionocyclus neptuni,* below occurrences of *Collignoniceras* sp. (Jones et al., 1978, p. XXII.8, figs. 5, 6).

REMARKS. The holotype is a nearly perfect shell, and is remarkably modern looking for a Turonian gastropod. It is very similar in shape and sculpture to *Cymia tecta,* type species of *Cymia,* from which it differs chiefly in its circumapertural denticulations and lack of the strong fold about midway of the inner lip. The sculpture of *P. aurora* resembles that of *Murphitys michaeli. M. michaeli* has a longer anterior canal which lacks the well-developed fasciole of *P. aurora.* Although the outer lip of *P. aurora* is thickened, it is not rimmed like that of *M. michaeli.*

ETYMOLOGY. *Aurora,* Latin, dawn, morning.

Pseudocymia(?) *aitha* new species

Figures 5, 109–112

DIAGNOSIS. Small *Pseudocymia*(?) with three strongest spiral ribs on the periphery, two of which are clearly evident on the spire. Within, the outer lip has three strong denticles near the periphery and small denticles near the anterior canal.

DESCRIPTION. Shell shortly fusiform, small; spire about half of height of shell, comprised of four post-nuclear whorls, each about twice as wide as high; apical angle approximately 42°; whorl outline angulate with shallowly concave ramp, peripheral angulation accentuated by three strong spiral ribs, base sloping straight to the anterior siphonal fasciole; anterior canal short, bent to the left and abaperturally; suture coincident with the abapical peripheral spiral cord.

Sculpture of narrow spiral ribs, weak posterior to the periphery, moderately strong on the periphery and base; interspaces wider than the ribs; peripheral spiral ribs made nodulose by about ten short but strong axial ribs.

Aperture broad posteriorly; outer lip expanded and thickened, with a posterior siphonal notch nearly midway between the suture and the periphery, bearing a posterior denticle just anterior to the siphonal notch, two strong denticles at the periphery, the posterior of which is the stronger, and three small denticles at anterior end of aperture; inner lip well marked, bearing two wrinkle-like denticles near anterior end of aperture, two pseudofolds anterior to the mid-point and three small denticles at beginning of anterior siphonal canal.

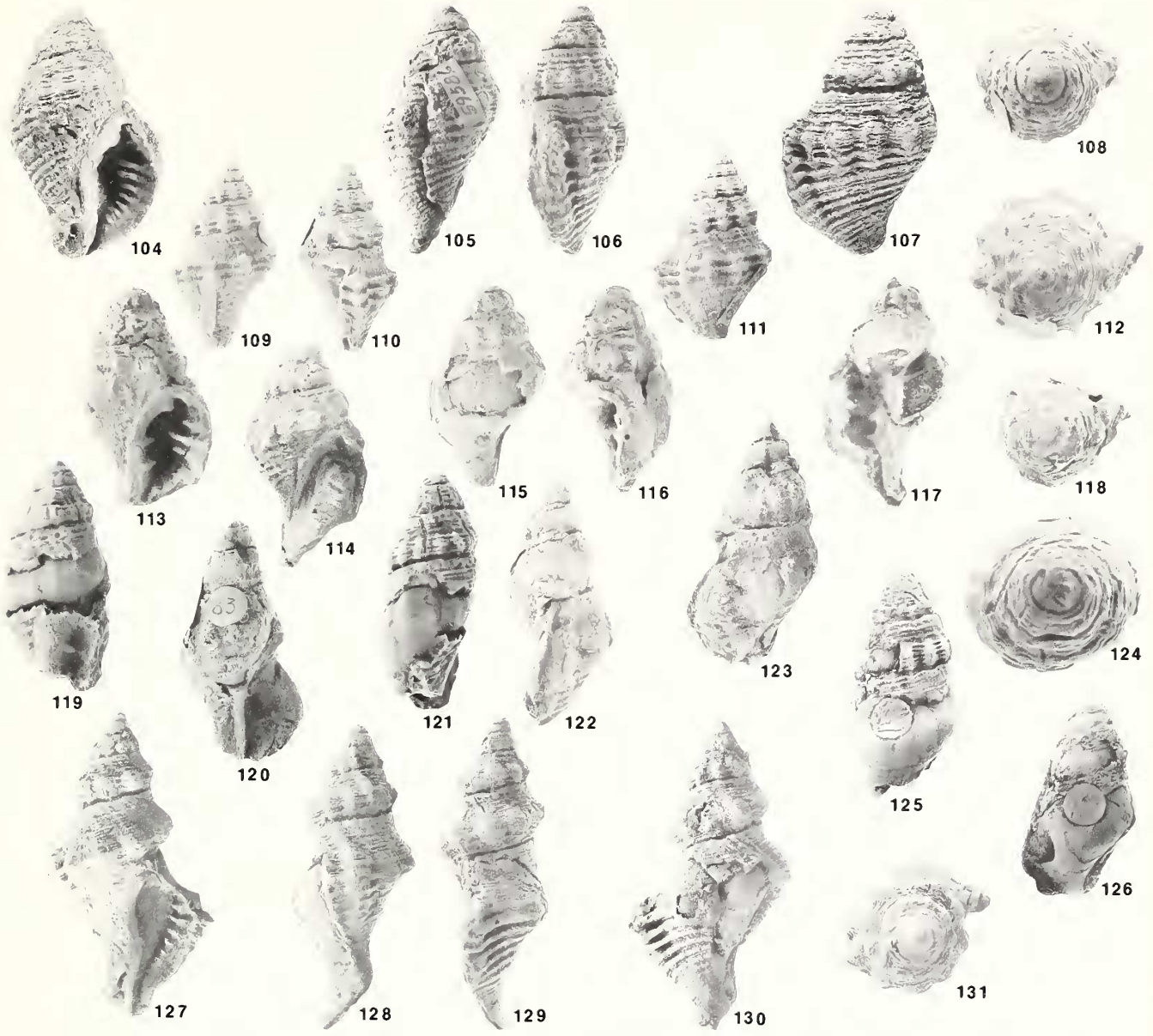
HOLOTYPE. UCLA 39440.

DIMENSIONS. Of holotype—height 28 mm (incomplete); diameter 18 mm; height of spire 14 mm.

TYPE LOCALITY. CIT loc. 1007, Oak Run, Millville Quadrangle, Shasta Co., California (area 11).

DISTRIBUTION. One specimen from Member IV of the Redding Formation in Oak Run, Millville Quadrangle (area 11) and a poorly preserved specimen from Member V, Bear Creek, Whitmore Quadrangle (area 11).

GEOLOGIC AGE. Coniacian.



Figures 104–131. Species of *Pseudocymia* new genus. All ×1 unless otherwise noted. **Figures 104–108.** *Pseudocymia aurora* new species, Turonian, holotype, UCLA 59586 from CIT loc. 1212; **104** and **108** photos by T. Susuki. **Figures 109–112.** *Pseudocymia*(?) *aitha* new species, Coniacian, holotype, UCLA 39440 from CIT loc. 1007; **112,** ×1.5. **Figures 113–118.** *Pseudocymia*(?) cf. *P.*(?) *aitha* new species, Santonian, hypotypes, ×2, from UCLA loc. 6496; **113, 115, 116, 118,** LACMIP 7261; **114, 117,** LACMIP 7262; **117,** the back of the last whorl is broken off and the pseudofolds and median outer lip denticulation are visible. **Figures 119–126.** *Pseudocymia*(?) *cahalli* new species, Campanian; **119, 121, 124, 125,** the anterior canal is broken off and the outer lip is crushed, holotype, LACMIP 7263 from UCLA 2324; **124,** ×1.5; **120, 122, 123,** paratype, UCLA 39473 from CIT loe. 83; a badly leached shell preserving only remnants of sculpture but more of the anterior canal including part of the anterior siphonal fasciole, breakage of the posterior end of the outer lip gives a false impression of its posterior outline; **126,** paratype, CAS 61618.01 from LSJU loc. 1860 with posterior end of outer lip preserved. **Figures 127–131.** *Pseudocymia*(?) *kilmeri* new species, early Maastrichtian, holotype, UCBMP 37997 from UCB loc. B-5323, edge of outer lip broken posterior to the periphery.

REMARKS. The holotype is well preserved and nearly complete, lacking part of the nucleus and the anterior end of the anterior siphonal canal. Although the growth line has an antispiral sinus, this sinus is not as sharply bent and deep as the posterior siphonal notch suggests that it should be. The notch may, therefore, have been deepened by an injury, and so definite a notch may not be characteristic of the species. Despite this deeper siphonal notch and the less fortified aperture, the species is included in *Pseudocymia* because of its overall shape and well-developed anterior fasciole.

Pseudocymia(?) *aitha* differs from *P. aurora* in its more angulate whorl profile, slightly more concave ramp, and fewer denticles on the outer lip. It is very similar to *Perissitys cretacea,* from which it differs in being less expanded about the periphery, having slightly stronger and fewer spiral ribs and longer axial ribs, more than one median denticle on the outer lip, and the most posterior portion of the inner lip abapical to the peripheral spirals rather than lapping over them.

ETYMOLOGY. *Aitha,* Greek, burnt, fiery, reddish-brown, for its occurrence near Redding, California.

Pseudocymia(?) cf. *P.*(?) *aitha* new species

Figures 113–118

HYPOTYPES. LACMIP 7261–7262 from UCLA loc. 6496.

DIMENSIONS. Of LACMIP 7261—height 16.8 mm, diameter 9.6 mm, height of spire 7 mm; of LACMIP 7262—height 17.4 mm, diameter 10 mm, height of spire 7 mm; both specimens are incomplete.

DISTRIBUTION. Two specimens from the Panoche Formation, Howard Ranch Quadrangle, Merced Co., California (area 8).

GEOLOGIC AGE. Santonian.

REMARKS. Two small incomplete specimens resemble *P.*(?) *aitha,* but are slightly more slender, have a less angulate whorl profile, and one or two more axial ribs per whorl. The posterior section of the outer lip is sulcate, but the notch is broader than that of *P.*(?) *aitha.* As in *P.*(?) *aitha* there is a posterior denticle just anterior to the siphonal notch and two strong denticles at the periphery, the posterior of which is stronger. These specimens are superficially similar to *M. michaeli,* but they are more slender, have fewer axial ribs per whorl, and the denticles on the outer lip are placed as in *P.*(?) *aitha.*

Pseudocymia(?) cahalli new species

Figures 119–126

DIAGNOSIS. Elongate *Pseudocymia*(?) with the outer lip ornamented by two strong denticles at the periphery, a posterior denticle of moderate size and small denticles near the anterior siphon.

DESCRIPTION. Shell of medium size, fusiform; spire of about five post-nuclear whorls, each about twice as wide as high; apical angle approximately 30°; whorl outline subangular with shallowly concave ramp, peripheral angulation accentuated by short axial ribs; suture just abapical to the periphery.

Sculpture of narrow subequal spiral ribs; interspaces wider than the ribs; periphery made nodulose by about ten short but strong axial ribs.

Aperture widest posteriorly; outer lip expanded and thickened by varix, bearing a pair of strong denticles opposite the periphery, a posterior denticle, and at least two smaller ones near the anterior siphon; inner lip of moderate width, thick, with a strong pseudofold opposite the periphery, a lesser one near the anterior siphon, one or two denticles at the anterior siphon, and one or two denticles near the posterior end.

HOLOTYPE. LACMIP 7263.

PARATYPES. UCLA 39473 from CIT loc. 83 and CAS 61618.01 from LSJU loc. 1860.

DIMENSIONS. Of holotype—height 35.7 mm (incomplete); maximum diameter 18.3 mm (incomplete); height of spire 17 mm.

TYPE LOCALITY. UCLA loc. 2324, Santa Ana Mountains, Orange Co., California (area 13).

DISTRIBUTION. Cedar District Formation, Sucia Island (area 18); and uppermost Holz Shale Member of Ladd Formation, Santa Ana Mountains (area 13).

GEOLOGIC AGE. Mid Campanian.

REMARKS. The above description is based upon three incomplete specimens; one from Sucia Island and two from the Santa Ana Mountains. None of the specimens retains the anterior siphonal canal, but there is an indication of a well-developed siphonal fasciole. The spiral ribs appear to be strongest anterior to the periphery. The short axial ribs are most numerous on the spire (about 14) but are reduced to about ten stronger ones on the ultimate whorl. The outer lip is poorly preserved on a paratype (UCLA 39473). Denticles within the outer lip are described from impressions on the infilling of the holotype and the second paratype (CAS 61618.01).

P.(?) *cahalli* is most similar to *P.*(?) *kilmeri,* from which it differs in having a less strongly angulate whorl profile, the suture closer to the noded periphery, and stronger pseudofolds on the columella.

ETYMOLOGY. The species is named for C.A. Hall.

Pseudocymia(?) *kilmeri* new species

Figures 127–131

DIAGNOSIS. Elongate *Pseudocymia*(?) expanded peripherally and contracted suturally, with six evenly spaced linear denticles within the outer lip between the periphery and the anterior canal. There are two weak pseudofolds on the columella.

DESCRIPTION. Shell medium sized, subfusiform with backward flexed short open anterior canal and small pseudoumbilicus; spire almost half of height of shell, comprised of five post-nuclear whorls, each about twice as wide as high; apical angle approximately 38°; profile of last three whorls concave adapical to the periphery, prior whorls convex; base sloping straight into constriction adapical to the siphonal fasciole; suture abapical to the periphery; shell broadened by indistinct varices at about 180°.

Overall sculpture of spiral riblets strongest on the peripheral angulation, progressively weaker from periphery to both sutures with weakest riblets on the sutural ramp and three or four strongest on the angulation, one to three threads between the riblets; about ten axially elongated nodes per whorl on the periphery; suture on fourth abapical strong rib.

Aperture widest posteriorly; outer lip thickened by varix, expanded medially, and bearing a strong denticle plus one or two smaller ones near the posterior end, two strong den-

ticles at the periphery and four of decreasing strength anteriorly; inner lip of moderate width and thickness with small denticles bordering the posterior notch, two faint pseudofolds just anterior to the midpoint and a low welt near the anterior end.

HOLOTYPE. UCBMP 37997.

DIMENSIONS. Height 47.4 mm; diameter 24.9 mm; height of spire 22.4 mm; height of penultimate whorl 10.3 mm; diameter of penultimate whorl 16 mm.

TYPE LOCALITY. UCB loc. B-5323: Punta San Jose, Baja California (area 10).

DISTRIBUTION. Rosario Formation, Punta San Jose (area 10).

GEOLOGIC AGE. Early Maastrichtian.

REMARKS. The above description is based upon the only known specimen, the nearly complete holotype. The outer lip is broken along the sutural ramp; the tip of the anterior canal is chipped; some shell is missing from the back of the body whorl, and the apex is eroded.

P.(?) *kilmeri* has much more subdued apertural ornament than *P. aurora,* but the denticulations are similarly placed. *P.*(?) *kilmeri* is also much more elongate, has a more fusiform shape, and slightly longer anterior canal. In sculpture and shape of base it resembles *P.*(?) *aitha,* but it is also more fusiform than *P.*(?) *aitha,* has a more abapical suture, and has stronger spiral ribs adapically to the three prominent ones on the periphery.

In shape and sculpture *P.*(?) *kilmeri* bears a strong resemblance to *Solenosteira* spp., especially *S. gatesi* Berry, 1963, of the modern Panamic fauna. It differs from *S. gatesi* most notably in the flare of its outer lip and the strength of the denticles within.

ETYMOLOGY. The species is named for F.H. Kilmer who collected the holotype at Punta San Jose, Baja California, Mexico.

Genus *Murphitys* new genus

TYPE SPECIES. *Murphitys michaeli* new species.

DIAGNOSIS. Plumply bucciniform gastropods of small to medium size which have a rounded to doubly subangulate whorl profile. Whorls are ornamented by spiral ribs, two of which predominate, and short axial ribs. Outer lip expanded to form a rim which is thickened at its edge and has posterior, medial, and anterior denticles within. Parietal lip is roundly expanded. Columella has two folds. Anterior canal is moderately long, slightly curved, and has a fasciole near its tip.

DISCUSSION. Characteristic of this genus is the rimmed outer lip with its inner surface rolled outward. The parietal lip is roundly expanded, although that of the earliest species, *M. michaeli,* is only slightly more expanded than the parietal lip of *Perissitys cretacea* or *Pseudocymia aurora,* both of which it resembles in shape and sculpture. The parietal lip is more roundly expanded in later species of *Murphitys* but is not as expansive as the parietal lip of *Perissitys* spp. *Murphitys* differs from *Perissitys* and *Pseudocymia* in having folds on the columella. The folds are faint on *M. michaeli* but become strong on *M. madonna.* Additional trends in this lineage lead to the loss of the posterior sinus on the outer lip and to a more angulate whorl profile.

The illustration of *Fusus* (s.l.) *volutodermoides* Nagao, 1939 (p. 231, pl. XXII, fig. 5) from the upper Yezo Group, Abeshinai, Teshio Prov., Japan, resembles *M. michaeli,* but that species is described as having a smooth columella.

RANGE. Coniacian to early Maastrichtian.

ETYMOLOGY. The name is a compound of Murphy (for M.A. Murphy) and *itys,* Greek, rim or felly of a wheel.

Murphitys michaeli new species

Figures 9, 132–147

DIAGNOSIS. Small *Murphitys* which have a rounded whorl profile and peripheral spirals that are scarcely stronger than the other spirals. The outer lip bears a strong medial denticulation. The two columellar folds are, although distinct, not strong.

DESCRIPTION. Shell small, bucciniform; spire about one-third of total shell height, consisting of about five whorls including a smooth mammillate protoconch of one whorl succeeded by whorl sculptured by raised spiral threads and axial ribs; all whorls roundly convex; base of whorl narrowing to form a sturdy anterior siphonal canal of moderate length and twisted to the left (apertural view) and backward at its tip; suture adapical to the whorl mid-point.

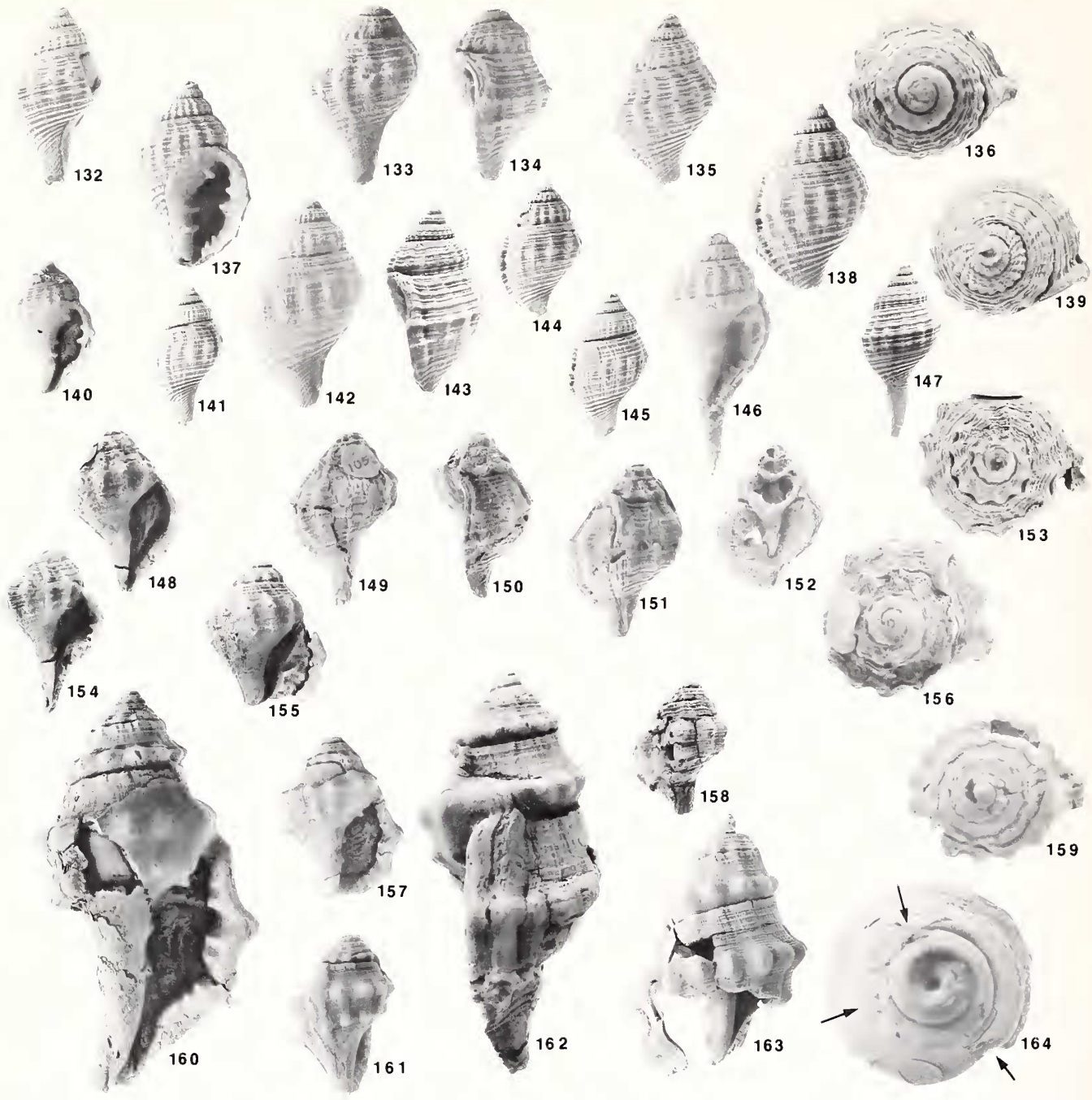
Sculpture of alternating spiral ribs and threads with interspaces usually a little wider than the ribs; two or three peripheral ribs slightly stronger and the suture on the most anterior of these; spiral sculpture undulated by arcuate collabral ribs which decrease in number to about 15 and in regularity and strength on the last whorl.

Outer lip thickened and slightly expanded to form a rimmed aperture with shallow antispiral sinus adapical to the periphery and slight spiral antisinus anterior to the periphery; inner lip fairly broad and thin, parietal portion roundly expanded onto the body whorl. Outer lip with two posterior denticles, a strong medial denticle and a clump of small denticles just posterior to the anterior canal; inner lip with a posterior denticle and two folds, the posterior one opposite the strong median denticle of the outer lip and the anterior one just posterior to the clump of outer lip denticles; an additional denticle sometimes present at the posterior end of the anterior canal.

HOLOTYPE. LACMIP 7264.

PARATYPES. LACMIP 7265–7269 from UCLA loc. 4106, 7270 from CIT loc. 1247, and 7271–7272 from CIT loc. 1230.

DIMENSIONS. Of holotype—height 19.7 mm, diameter 13.0 mm, height of spire 7.7 mm; of paratypes—LACMIP 7265, height 28.4 mm, diameter 13.2 mm, height of spire 8.6 mm; LACMIP 7267, height 22.0 mm, diameter exclusive of outer lip flare 12.6 mm (including outer lip flare 14.3 mm), height of spire 8.0 mm; LACMIP 7270, height 23.0 mm, diameter 12.9 mm, height of spire 7.8 mm; LACMIP 7271, height 19.6 mm, diameter 13.7 mm, height of spire 5.4 mm;



Figures 132–164. Species of *Murphitys* new genus. All ×1 unless otherwise indicated. As nearly as possible the figures are arranged from geologically oldest to youngest. **Figures 132–147.** *Murphitys michaeli* new species. **132–136,** Coniacian; **137–147,** Santonian; **132, 135,** paratype LACMIP 7272 from CIT loc. 1230, ×1.5; **133, 134, 136,** paratype, LACMIP 7271 from CIT loc. 1230; **133, 134,** ×1.5; **136,** ×2; **137–139, 143,** holotype, LACMIP 7264 from UCLA loc. 4106; **137, 138, 143,** ×1.5; **139,** ×2; **140,** paratype with more of anterior canal preserved, LACMIP 7268 from UCLA loc. 4106; **141, 145,** paratype with subdued axial sculpture, LACMIP 7270 from CIT loc. 1247; **142,** paratype, LACMIP 7266 from UCLA loc. 4106, ×1.5; **144,** paratype with moderate axial sculpture, LACMIP 7267 from UCLA loc. 4106; **146,** paratype with part of last whorl cut away and columellar folds exposed, LACMIP 7269 from UCLA loc. 4106, ×1.5; **147,** paratype with nearly complete anterior canal, LACMIP 7265 from UCLA loc. 4106. **Figures 148–156.** *Murphitys corona* new species, early Campanian, all from CIT loc. 1053. **148–151, 156,** holotype, LACMIP 7273; **156,** ×1.5; **152,** paratype with back cut away and columellar folds exposed, LACMIP 7275; **153, 155,** paratype with more fully developed outer lip, LACMIP 7274; **153,** ×1.5; **154,** paratype with nearly complete anterior canal and anterior siphonal fasciole, LACMIP 7276. **Figures 157–164.** *Murphitys madonna* new species, early Maastrichtian. **157, 161,** paratype, SDSNH 25942 from SDSNH loc. 3162A; **158,** paratype, LACMIP 7277 from LACMIP loc. 4898, ×1.5; **159, 163,** paratype with last whorl broken and columellar folds exposed, SDSNH 27871 from SDSNH loc. 3162A; **160, 162,** holotype, SDSNH 25958 from SDSNH loc. 3161A; **164,** paratype, steinkern with impressions of outer lip armaments at varices (arrows), LACMIP 7278 from UCLA loc. 5431.

LACMIP 7272, height 19.3 mm, diameter 11.9 mm; height of spire 7.4 mm.

TYPE LOCALITY. UCLA loc. 4106, hillside north of Clover Creek, Millville Quadrangle, Shasta Co., California (area 11).

DISTRIBUTION. Member IV along Oak Run (area 11) and Members V and VI along Clover Creek (area 11); ?Kingsley Cave Member of the Chico Formation on Mill Creek (very poor specimens) (area 2).

GEOLOGIC AGE. Coniacian and Santonian.

REMARKS. *Murphitys michaeli* resembles *Perissitys cretacea* but differs from it in having a more convexly rounded whorl profile with a concave ramp only on the last third of the last whorl. The first and second post-nuclear whorls of *M. michaeli* are virtually indistinguishable from those of *Perissitys elaphia.* Juvenile specimens of the two species then become distinguishable as *P. elaphia* develops a concave ramp. *M. michaeli* does not have as expanded an inner lip as *P. elaphia* nor as long an anterior canal. *M. michaeli* is similar to *Pseudocymia aurora* in its apical profile and sculpture but differs in being more constricted anterior to the periphery, having a rounded whorl profile and a broader, thinner, roundly expanded inner lip, lacking a pseudoumbilicus, and having fewer denticles on the outer lip.

Strength of spiral ribbing is variable in *M. michaeli.* Peripheral spirals are in some specimens scarcely stronger than those anterior and posterior, but in other specimens two peripheral spirals are strong enough to give the whorl a subangulate profile.

In apertural view the anterior fold is the more prominent one, its outer end being farther out on the inner lip, and the posterior fold is much less noticeable, its outer end being well within the aperture. The posterior is the more prominent fold away from the aperture within the spire. Both are, however, not strong except at varices.

ETYMOLOGY. The species is dedicated to Michael A. Murphy in recognition of his work on the Cretaceous of the Ono area, Shasta Co., California.

Murphitys corona new species

Figures 146–156

DIAGNOSIS. Plump *Murphitys* which have a doubly subangulate periphery demarked by the two strongest spiral ribs. The outer lip bears about five nearly equal denticulations.

DESCRIPTION. Shell of medium size, roundly buccinifform; spire less than one-third of total shell height, consisting of about four post-nuclear whorls; protoconch unknown; whorls roundly convex with slightly concave ramp and double angulation at the periphery; last whorl narrowing to form a sturdy, nearly straight, anterior canal of moderate length; suture between the peripheral angulations.

Sculpture of alternating spiral ribs and threads with interspaces about twice as wide as the ribs; two slightly stronger ribs on the two angulations; ribbing anterior to the periphery a little stronger than that posterior to the periphery; spiral sculpture undulated by slightly arcuate, broadly rounded collabral ribs that number 11–14 on the last whorl; angulations noded at intersections with collabral ribs.

Outer lip thickened, slightly expanded, and somewhat recurved to form a rimmed aperture with shallow antispiral sinus adapical to the periphery and slight spiral antisinus anterior to the periphery; inner lip broad and thin, roundly expanded onto the body whorl. Outer lip with about five nearly equal denticles and 2–3 denticulations adjacent to the anterior canal; columella with two folds and a parietal denticle, the stronger fold at the base of the previous whorl, the weaker one near the posterior end of the anterior canal.

HOLOTYPE. LACMIP 7273.

PARATYPES. LACMIP 7274–7276 from CIT loc. 1053.

DIMENSIONS. Of holotype—height 26.8 mm; diameter 18 mm, height of spire 7.5 mm.

TYPE LOCALITY. CIT loc 1053: spur north of Santiago Creek, El Toro Quadrangle, Santa Ana Mountains, Orange Co., California (area 13).

DISTRIBUTION. Ladd Formation, upper Holz Shale Member, Santa Ana Mountains (area 13); and Chatsworth Formation, Bell and Dayton canyons, Simi Hills (area 17).

GEOLOGIC AGE. Early Campanian, associated with *Canadoceras* cf. *C. yokoyamai* (Jimbo) (Matsumoto, 1960, p. 102), zone of *Turritella chicoensis holzana* Saul, 1983, through late Campanian *Metaplacenticeras pacificum* Zone.

REMARKS. The double corona of distinct nodes at the periphery distinguishes this species from all other perissityids. The species is based on nine specimens from CIT loc. 1053. A poorly preserved specimen from CIT loc. 94, Ladd Formation, uppermost Holz Shale Member, *T. chicoensis* Zone, of Williams Canyon, Santa Ana Mountains, and juvenile specimens from Bell (CIT loc. 1158) and Dayton canyons (CIT loc. 1159), Chatsworth Formation, *T. chicoensis* and *Metaplacenticeras pacificum* zones, Simi Hills (area 17) are also probably this species.

The more posterior of the two columellar folds appears weaker in apertural view because it begins farther back within the aperture, whereas the stronger appearing anterior fold not only begins farther out toward the inner lip but is also at its strongest at that point and weakens within the whorl.

Juveniles of *Perissitys brevirostris* and *P. pacifica* are similar to *M. corona,* but the latter is more distinctly bicoronate. Adult *M. corona* lack the sutural welt of adult *P. brevirostris* and *P. pacifica.*

ETYMOLOGY. *Corona,* Latin, both for its corona of nodes on the periphery and its occurrence in the old Corona Quadrangle.

Murphitys madonna new species

Figures 157–164

Perissitys brevirostris (Gabb) Sundberg & Riney, 1984, p. 105, fig. 3.3. Not *Perissolax brevirostris* Gabb, 1864.

DIAGNOSIS. Moderately large, biangulate *Murphitys* which have four subequal denticulations along the outer lip and two strong folds on the columella.

DESCRIPTION. Shell large, doubly angulate about the broad periphery; spire about one-third of the total shell height, consisting of about six post-nuclear whorls; protoconch apparently smooth and relatively large; whorls concave on the

ramp with double angulation at the periphery; last whorl narrowing to form a sturdy, slightly backward deflected anterior canal, bent abaperturally at its tip, longer than the height of the last whorl, and having a siphonal fasciole at its tip; suture at or just abapical to the adapical angulation, on the first four post-nuclear whorls, dropping to just above the abapical angulation on the last whorl.

Sculpture of fine alternating spiral ribs and threads with interspaces about three times as wide as the ribs; ribbing anterior to the abapical peripheral angulation a little stronger than that posterior to the abapical peripheral angulation; on third post-nuclear whorl about nine short collabral ribs forming strong nodes at their intersections with the two peripheral angulations, increasing to 16 on sixth whorl.

Outer lip thickened, forming a rimmed leaf-shaped aperture; inner lip broad and of moderate thickness, parietal portion roundly expanded onto the body whorl. Outer lip with a pair of denticles posterior to the notch at the adapical angulation, a pair of denticles between the angulations and three to four smaller denticles between the abapical angulation and the anterior canal; columella with two folds and a parietal denticle, the stronger fold at the base of the previous whorl, the weaker one near the posterior end of the anterior canal.

HOLOTYPE. SDSNH 25958.

PARATYPES. LACMIP 7277 from LACMIP loc. 4898, 7278 from UCLA loc. 5431, 7279 from UCLA loc. 7137, 7280 from LACMIP loc. 1215, and 7281 from LACMIP loc. 8159; SDSNH 25942 and 27871 from SDNH loc. 3162-A.

DIMENSIONS. Of holotype—height 64.5 mm, diameter 35.1 mm, height of spire 23.6 mm.

TYPE LOCALITY. SDSNH loc. 3162-A, Carlsbad Research Park, San Diego Co., California (area 20).

DISTRIBUTION. Chatsworth Formation on Lang Ranch, Simi Hills (area 17); Pleasants Sandstone Member of Williams Formation, Bean Creek, east of San Juan Capistrano (area 24); Rosario Formation near Carlsbad (Point Loma Member) (area 20), at Punta Banda (area 22), near Punta San Jose (area 10), near San Antonio del Mar (area 12), and at Arroyo Santa Catarina (area 14).

GEOLOGIC AGE. ?Latest Campanian and early Maastrichtian.

REMARKS. Although more than 20 specimens of this species are at hand, most are poorly preserved. The best specimens are from the Carlsbad Research Park. Small specimens are roundly inflated like *Murphitys corona,* but have fewer and stronger nodes about the periphery. Large specimens are much more angulate and resemble stout "*Fusus*" *kingii* Gabb, 1864. They have, however, the rimmed aperture and roundly expanded inner lip of *Murphitys.* As in many other perissityids, steinkerns of the species have at intervals impressions of the outer lip denticles (Figure 164) left by the irregular development of the varices.

A medium-sized specimen (LACMIP 7281) from LACMIP loc. 8159, east of San Juan Capistrano (area 24) occurs with *Baculites* cf. *B. subanceps pacificus* Matsumoto & Obata, 1963. This baculite is considered to be of late Campanian age (Matsumoto with Miyauchi, 1984, p. 75), but some other mollusks from LACMIP loc. 8159 are not typical of late Campanian faunas: *Calva peninsularis* (Anderson & Hanna, 1935), *Paleomoera dyskritos,* Dailey & Popenoe, 1966, and a large undescribed parallelodontid have all been found in beds of early Maastrichtian age.

ETYMOLOGY. From Madonna Hill on El Camino Real, east of Carlsbad, San Diego Co., California.

Genus *Christitys* new genus

TYPE SPECIES. *Christitys medica* new species.

DIAGNOSIS. Compactly turriculate to pyriform gastropods of small to moderate size with an angulate whorl periphery made nodose by short axial ribs. Aperture deltoid in shape with a broad posterior sinus adapical to the whorl periphery. Outer lip with posterior and medial denticulations. Columella with a fold near the base of the previous whorl and posterior and anterior denticulations.

DISCUSSION. *Christitys* resembles *Murphitys* in having a columellar fold but is more sharply angulate about the periphery and has fewer denticulations on the outer lip. The outer lip denticulations are weaker in the geologically younger *C. martini* than they are in *C. delta* or *C. medica.* Conversely, the posterior denticulations of the inner lip are stronger in *C. martini* than in *C. delta. C. martini* has a shorter spire and more pyriform shape and resembles *Heteroterma* Gabb, 1869. *Heteroterma* differs from *Christitys* in lacking columellar folds. *Cominella*? *praecursor* Wilckens, 1907, from the late Senonian of southern Patagonia was placed in *Heteroterma* by Finlay and Marwick (1937), but the aperture is not described (Wilckens, 1907, p. 117). The figures of *C.*? *praecursor* are suggestive of *Christitys.* The lack of columellar folds in *Heteroterma* is not considered by us to preclude a close relationship to *Christitys.*

ETYMOLOGY. The generic name is a compound of Christie (for J.M. Christie), and *itys,* Greek, rim or felly of a wheel.

Christitys delta new species

Figures 8, 165–168

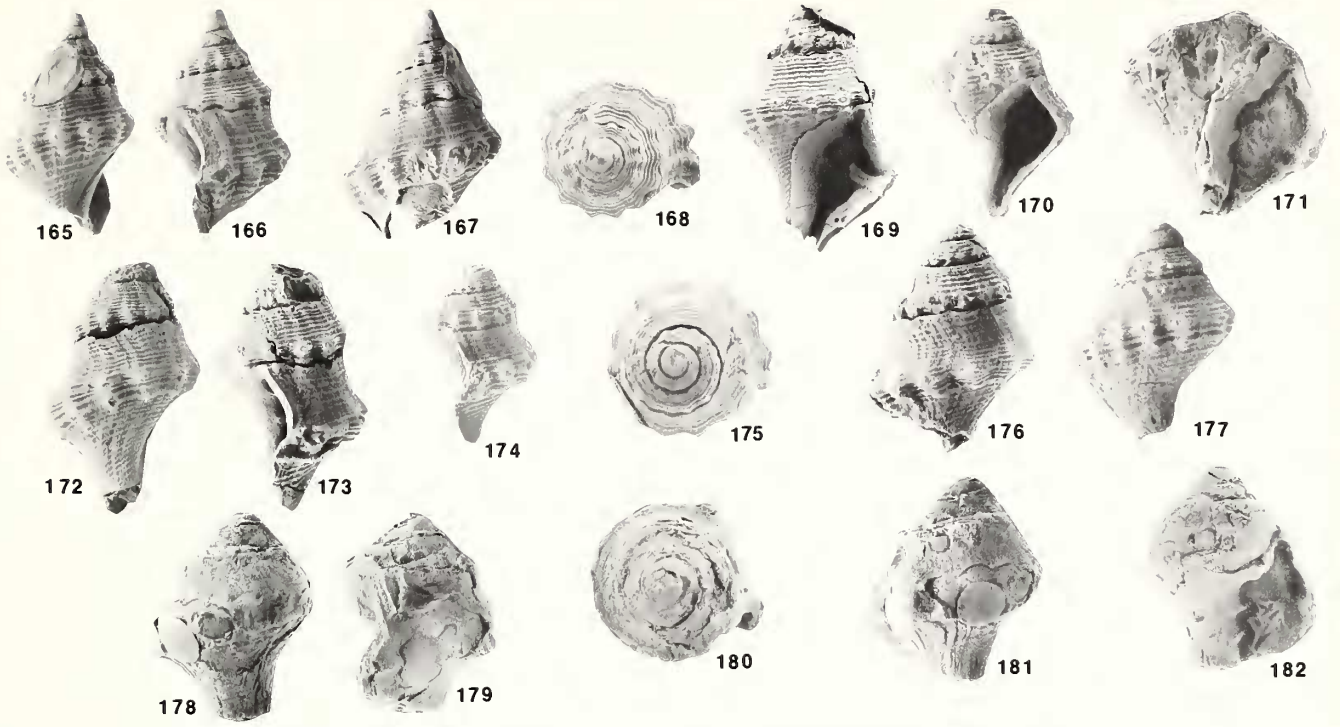
DIAGNOSIS. Compactly turriculate *Christitys* which have a sharply angulate periphery.

DESCRIPTION. Shell small, compactly turriculate; spire consisting of about four whorls and a smooth, mammiform protoconch of one and a half whorls succeeded by a whorl sculptured by raised spiral threads; first two whorls roundly convex; others concave on the ramp, angulate at the periphery, and abruptly contracted abapically.

Sculpture of spiral ribs narrower than the interspaces, strongest on the angulate periphery, weakest on the ramp; periphery made nodose by 14 very short axial ribs.

Outer lip with a shallow antispiral sinus adapical to the periphery and moderate spiral antisinus anterior to the periphery; inner lip well demarked and of moderate and nearly constant width. Outer lip with two tiny posterior denticles and a moderately strong coalesced pair just anterior to the peripheral angulation; inner lip with a moderate parietal denticle, a fold on the columella just at the base of the previous whorl and an anterior pseudofold.

HOLOTYPE. UCLA 39455.



Figures 165–182. Species of *Christitys* new genus. All ×1.5 unless otherwise noted. **Figures 165–168.** *Christitys delta* new species, holotype, Coniacian, UCLA 59455 from UCLA loc. 4209. **Figures 169, 170, 172–177.** *Christitys medica* new species, Santonian, all from UCLA loc. 4106; **169, 172, 173,** holotype, LACMIP 7282; **170,** paratype, LACMIP 7286, ×2, a juvenile; **174,** paratype LACMIP 7284, a young specimen with nearly complete outer lip; **175, 176,** paratype LACMIP 7283; **177,** paratype LACMIP 7285, ×2. **171, 178–182.** *Christitys martini* new species, Campanian, all from USGS 5795, ×1; **171,** paratype USNM 400976; **178–182,** holotype, USNM 400975.

DIMENSIONS. Height 20.2 mm; diameter 14.9 mm; height of spire 10.2 mm.

TYPE LOCALITY. UCLA loc. 4209, north side of Clover Creek valley, Millville Quadrangle, Shasta Co., California (area 11).

DISTRIBUTION. Known only from the type locality in Member IV on Clover Creek (area 11).

GEOLOGIC AGE. Coniacian.

REMARKS. The above description is based upon the holotype and only known specimen. The spire is very well preserved, but unfortunately the anterior canal is broken off. This specimen is higher spired, more sharply angulate at the periphery, and more coarsely sculptured than any specimen assigned to *C. medica.* It differs from *Perissitys cretacea* and *Murphitys michaeli* in having its suture very close to its angulate whorl periphery, which produces a nearly triangular spire.

ETYMOLOGY. The species is named *delta,* fourth letter of the Greek alphabet, for its triangular spire.

Christitys medica new species

Figures 169, 170, 172–177

DIAGNOSIS. Compactly turriculate *Christitys* which have an angulate periphery broad enough to display three to four spiral ribs.

DESCRIPTION. Shell small, compactly turriculate; spire consisting of about four whorls (protoconch not observed), first whorl convexly rounded and spirally sculptured; second whorl with flat ramp, spiral sculpture and angulate, noded periphery; third and fourth whorls with slightly concave ramp; angulate noded periphery abruptly contracted anteriorly, produced into siphonal neck of moderate length.

Sculpture of spiral ribs narrower than the interspaces, three to four strongest on the angulate periphery made nodose by about 13 very short axial ribs.

Outer lip with a shallow antispiral sinus between the suture and the periphery and moderate spiral antisinus anterior to the periphery, slightly flared anterior to the periphery; inner lip well demarked and of moderate and nearly constant width. Outer lip with small denticle posterior to the periphery, a strong bifid denticle just anterior to the periphery, abapically a moderate denticle, and tiny denticles adjacent to the anterior canal; inner lip with a well-developed parietal denticle, a fold opposite the periphery, and an anterior pseudofold, all of apparently equal strength.

HOLOTYPE. LACMIP 7282.

PARATYPES. LACMIP 7283–7286, all from UCLA loc. 4106.

DIMENSIONS. Of holotype—height 21.8 mm (incomplete), diameter 15.2 mm; height of spire 9.3 mm (incomplete); of paratypes—LACMIP 7283, height 20.2 mm (in-

complete), diameter 15.2 mm, height of spire 9.7 mm; LACMIP 7286, height 8.6 mm, diameter 9.9 mm, height of spire 4.2 mm.

TYPE LOCALITY. UCLA loc. 4106, hillside north of Clover Creek, Millville Quadrangle, Shasta Co., California (area 11).

DISTRIBUTION. All specimens are from the type locality in Member VI on Clover Creek, Shasta Co., California.

GEOLOGIC AGE. Santonian.

REMARKS. None of the seven specimens is complete. *C. medica* differs from *C. delta* in its slightly broader periphery and in having the suture slightly more abapical to the periphery, giving the spire a slightly more turriculate shape. Except for the stronger peripheral ribs, the ribbing is overall of more even strength on *C. medica.* The denticulations of the outer lip, especially the large bifid denticle, resemble those of the "*Fusus*" *kingii* lineage (Figures 6, 14). In external shape and sculpture the species is most similar to Santonian age "*Hindsia nodulosa,*" but *C. medica* has a shorter spire, appears to have had a shorter anterior canal, and has the large bifid denticle within the outer lip rather than the two denticles present in "*H. nodulosa*" (Figure 12).

ETYMOLOGY. The specific name is from Latin, *medica,* clover from Media, for its occurrence on Clover Creek.

Christitys martini new species

Figures 171, 178–182

DIAGNOSIS. Pyriform *Christitys* which have a bluntly angulate periphery defined by two spiral ribs.

DESCRIPTION. Shell of moderate size, apparently pyriform; spire consisting of about four whorls (protoconch unknown); last whorl with slightly concave ramp, bluntly angulate periphery, contracted abruptly anterior to the periphery to form an anterior canal of unknown length.

Sculpture of spiral riblets narrower than the interspaces and two strong ribs defining anterior and posterior sides of the periphery; periphery made nodose by about 12 very short axial ribs.

Outer lip with a shallow antisiphonal sinus between the suture and the anterior side of the periphery and slight spiral antisinus anterior to the periphery, not flared; inner lip well demarked, a little expanded posteriorly. Outer lip thickened with denticle about midway along the ramp, a moderately strong bifid? denticle at the anterior side of the periphery, and abapically a moderate denticle; inner lip with a thick tripartite parietal denticle, a fold opposite the periphery, and an anterior pseudofold.

HOLOTYPE. USNM 400975.

PARATYPES. USNM 400976–400977 from USGS loc. 5795 and 400978 from USGS loc. 5796.

DIMENSIONS. Of holotype—height 27 mm (incomplete), diameter 25 mm, height of spire 8.5 mm.

TYPE LOCALITY. USGS loc. 5795, Whalers Creek, near Chignik Lagoon, Alaska Peninsula, Alaska (area 23).

DISTRIBUTION. Lower member of Chignik Formation, *Inoceramus schmidti* Zone near Chignik Bay, Alaska Peninsula.

GEOLOGIC AGE. Early Campanian. Ward et al. (1983) place the *Inoceramus schmidti* Zone in the Santonian because magnetic anomaly 33–34 occurs above *I. schmidti* in the Great Valley Series of California. Jones (1963, p. 432), however, records *Canadoceras newberryanum* throughout the Chignik Formation, and *C. newberryanum* occurs above magnetic anomaly 33–34 on Chico Creek (area 5). The Chignik Formation specimens may be of early Campanian age.

REMARKS. The species is based on four specimens from the Chignik Formation listed by Martin (1926, p. 304) as *Perissolax brevirostris.* These specimens are worn and broken, but the apertural characteristics are those of *Christitys. C. martini* differs from *C. medica* in having a broader periphery, shorter spire, and more expanded inner lip; from *Perissitys brevirostris* in having apertural decorations, and a much less expanded inner lip; from *P. elaphia* in having a fold on the columella, a deeper antispiral sinus to the growth line, two rather than three or four strong spirals at the periphery, and a much less expanded inner lip. The strong outer lip denticles of *C. martini* are at and abapical to the periphery as in *C. delta* and *C. medica* rather than at and adapical to the periphery as in *P. cretacea* and *P. elaphia. C. martini* resembles *Murphitys corona* in shape, but has a more pronounced antispiral sinus to the growth line; the outer lip is not rimmed, and the inner lip is less expanded.

Christitys martini resembles *Pseudoperissitys bicarinata* Nagao & Otatume, 1938 (pl. 4, fig. 3-5a), but *P. bicarinata* lacks columellar folds and outer lip thickening. It is said to be of Campanian or Maastrichtian age, and may be closely related to *Christitys.* In shape *C. martini* also resembles *Heteroterma trochoidea* Gabb, but the latter is without apertural ornament and has a thin inner lip, is from the Paleocene "Martinez Stage," and is considerably younger. The apertural ornaments, which appear to be reduced in *C. martini,* could have been lost by Paleocene time, and *Heteroterma* may be related to *Christitys.* The relationships of these three apparently similar genera need further study.

ETYMOLOGY. The species is named for G.C. Martin who recorded the specimens from the Chignik Formation.

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LOCALITIES CITED

Approximately one-third of the cited localities have been previously published; these are cited briefly with a reference. The italicized number to the left refers the locality to an area of Figure 1.

13 83 CIT (= UCLA 2949): Fine ss just above shale, section line fence gate on old road, ¼ mi. W of Schultz Ranch, S side of Williams Canyon, approx. 435 ft. S of NW cor. sec. 20, T5S, R7W, El Toro Quad., Santa Ana Mts., Orange Co., Calif. Coll.: B.N. Moore, 1926. Ladd Formation, uppermost Holz Shale Member. Mid Campanian, *Turritella chicoensis* Zone.

13 94 CIT: Sandstone just above shale about 300 ft. E of section line on ridge N of Williams Canyon, 500 ft. N, 300 ft. E of SW cor. sec. 17, T5S, R7W, El Toro Quad., Santa Ana Mts., Orange Co., Calif. Coll.: B.N. Moore, 1928. Ladd Formation, uppermost Holz Shale Member. Mid Campanian, *Turritella chicoensis* Zone.

7 249 UCB: ⅝ mi. W of Muir Station, ¼ mi. N of Franklin Creek, Concord Quad., Contra Costa Co., Calif. Coll.: J.C. Merriam. Great Valley Series. ?Late Maastrichtian.

8 460 LSJU: 300 ft. S, 650 ft. W of NE cor. sec. 24, T14S, R11E, Chounet Ranch Quad., Panoche Hills, Fresno Co., Calif. Basal Laguna Seca Formation, 300 ft. below base of Domengine. ?Late Danian.

8 463 CAS (= CAS 2362): Center E side sec. 4, T20S, R14E, north side Los Gatos Creek, Coalinga Quad., Fresno Co., Calif. Coll.: F.M. Anderson. Panoche Formation, "Ragged Valley Shale Member." Early Maastrichtian.

13 974 CIT: Aliso-Santiago Creek divide, El Toro Quad., Orange Co., Calif. Williams Formation, Pleasants Sandstone Member. Late Campanian. (Matsumoto, 1960, p. 99.)

11 1007 CIT: Oak Run, Millville Quad., Shasta Co., Calif. Member IV. Coniacian. (Matsumoto, 1960, p. 100.)

5 1016 CIT: Chico Creek, Paradise Quad., Butte Co., Calif. Chico Formation, Musty Buck Member. Santonian. (Matsumoto, 1960, p. 101.)

5 1017 CIT: Chico Creek, Paradise Quad., Butte Co., Calif. Chico Formation, Musty Buck Member. Santonian. (Matsumoto, 1960, p. 101.)

11 1034 CIT: See UCLA 4104.

13 1053 CIT (= UCLA 4191): N of Santiago Creek, El Toro Quad., Orange Co., Calif. Ladd Formation, upper Holz Shale Member. Early Campanian. (Matsumoto, 1960, p. 102.)

8 1068 LSJU: S of Chaney Ranch Canyon, W½, SW¼ sec. 19, T14S, R12E, Chounet Ranch Quad., Panoche Hills, Fresno Co., Calif. Coll.: R.T. White. Laguna Seca Formation. ?Late Danian or ?early Selandian.

17 1158 CIT (= UCLA 6020): SE slope of Simi Hills, N bank Bell Canyon, 1.15 mi. due W of Los Angeles–Ventura Co. line on boundary (extended) between T1 and 2N, Calabasas Quad., Ventura Co., Calif. Coll.: W.P. Popenoe, June 18, 1935. Chatsworth Formation. Late mid Campanian.

17 1159 CIT: Prominent fossil bed on crest of spur between forks of Dayton Canyon, about 400 ft. E of Los Angeles–Ventura Co. line, approx. 400 ft. N, 2350 ft. W of SE cor. sec. 28, T2N, R17W, Calabasas Quad., Los Angeles Co., Calif. Chatsworth Formation. Late Campanian. (Popenoe et al., 1987, p. 98.)

11 1212 CIT: Little Cow Creek, Millville Quad., Shasta Co., Calif. Frazier Siltstone (= Member II), hard sandy concretions, in shale. Late Turonian. (Popenoe, 1983, p. 765.)

14 1215 LACMIP: Mollusks and echinoid from Arroyo Santa Catarina, approx. 6 km N, 6 km E of mouth of Rio Santa Catarina, Baja California, Mexico. Coll.: H. Dushane, July, 1958. Rosario Formation. Early Maastrichtian.

11 1227 CIT (= UCLA 3296): Massive sandstone interbedded with conglomerate on S side of high E–W trending ridge, S side Oak Run Valley, 3275 ft. S 54°50′W of SE cor. sec. 10, T32N, R2W, Millville Quad., Shasta Co., Calif. Coll.: Popenoe & Ahlroth, 1936. Member V. Early Santonian.

11 1230 CIT: SE side Oak Run valley, SE of Dry Creek, S side of hill on section line between sections 11 & 14, 200 ft. S, 1750 ft. E of NW cor. sec. 14, T32N, R2W, Millville Quad., Shasta Co., California. Coll.: Popenoe & Ahlroth, 1936. Member V. Coniacian.

11 1232 CIT: Price Hollow, Millville Quad., Shasta Co., Calif. Member V, cross-bedded sandstones interbedded with thick conglomerate. Early Santonian. (Saul, 1978, p. 56.)

11 1246 CIT: Clover Creek, loose boulder on hillslope on E side of 1000 ft. hill, about 0.3 mi. NE of Reinicke's Ranch house, SE¼, NE¼ sec. 13, T32N, R2W, Millville Quad., Shasta Co., Calif. Coll.: Popenoe, 1936. Member V. Santonian.

11 1247 CIT: N side Clover Creek, Millville Quad., Shasta Co., Calif. Member V. Santonian. (Matsumoto, 1960, p. 104.)

7 1258 USGS: Near Blum and Company's Pacheco warehouse, about 1½ mi. N of Pacheco, Contra Costa Co., Calif. Coll.: T.W. Stanton, 1894. Great Valley Series. Late Maastrichtian.

11 1289 CIT: Bear Creek, at stone culvert on road to Aldridge's, SW of Bonnie Crags, about ½ mi.

W of Aldridge's and 1.3 mi. E of road forks and 2 mi. E of road crossing of N fork Bear Creek, 2000 ft. S, 500 ft. E of NW cor. sec. 18, T31N, R1E, Whitmore Quad., Shasta Co., Calif. Coll.: W.P. Popenoe & H.V. Church, August 17, 1936. Member V. Coniacian.

18 1400 CIT: Sucia Island, Orcas Island Quad., San Juan Co., Wash. Cedar District Formation. Mid Campanian, *Hoplitoplacenticeras* Zone. (Matsumoto, 1960, p. 107.)

18 1402 CIT: Float from base of cliffs on S side of Fossil Cove near W end, Sucia Island, sec. 26, T38N, R2W, Orcas Island Quad., San Juan Co., Wash. Cedar District Formation. Mid Campanian.

11 1532 CIT: Salt Creek, Millville Quad., Shasta Co., Calif. Frazier Siltstone (= Member II), near top. Turonian. (Matsumoto, 1960, p. 107.)

19 1581 UCLA: N side East Fork Fish Canyon, Warm Springs Mountain Quad., NW San Gabriel Mts., Los Angeles Co., Calif. San Francisquito Formation. Late Danian. (Saul, 1983, p. 112.)

19 1594 UCLA: N side Warm Springs Mt., Warm Springs Mountain Quad., Los Angeles Co., Calif. San Francisquito Formation. Late late Maastrichtian. (Saul, 1983, p. 113.)

11 1596 CIT: Forks of Snow and North Bear creeks, 2750 ft. S, 1250 ft. E of NW cor. sec. 7, T32N, R1E, Whitmore Quad., Shasta Co., Calif. Coll.: W.P. Popenoe & W.M. Tovel, September 10, 1941. Member V. Coniacian.

7 1602 CIT: NW side of crest of ridge just W of prominent bend in highway between Martinez and Crockett, 500 ft. NW of CIT 1601, approx. 1.8 mi. N 75° W of shore end of ferry pier at Martinez, and S of Benicia city wharf, Benicia Quad., Contra Costa Co., Calif. Coll.: W.P. Popenoe, Nov. 14, 1944. Great Valley Series, upper sandstone just below Martinez. Late Maastrichtian.

18 1860 LSJU: South end of Sucia Island also northwest islet of Sucia Group, Puget Sound, Orcas Island Quad., San Juan Co., Wash. Coll.: F.L. Cole, 1893. Cedar District Formation. ?Mid Campanian.

8 2245 LSJU: Between Marca Canyon and Chaney Ranch Canyon, 100 ft. S, 700 ft. W of NE cor. sec. 24, T14S, R11E, Chounet Ranch Quad., Panoche Hills, Fresno Co., Calif. Coll.: R.A.C. Brown, S. Muller, M. Payne & H.G. Schenck, 1940. Basal Laguna Seca Sand, 300 ft. below base of Domengine. ?Late Danian or ?early Selandian.

13 2324 UCLA: Just E of Santiago Creek, S of Williams Canyon and N of Modjeska Canyon, limey ss at top of Holz exposed in abandoned road cut in large gully, 4200 ft. N 70° W of mouth of Harding Canyon, NW¼, NW¼ sec. 29, T5S, R7W, El Toro Quad., Santa Ana Mts., Orange Co., Calif. Coll.: W.P. Popenoe, 1946. Ladd Formation, uppermost Holz Shale Member. Mid Campanian.

13 2415 UCLA: Spur NW side Bee Canyon, El Toro Quad., Orange Co., Calif. Williams Formation, Pleasants Sandstone Member. (Saul, 1978, p. 56.)

14 2852 LACMIP: West side Arroyo Santa Catarina, Estado de Baja California, Mexico. Rosario Formation. Early Maastrichtian. (Webster, 1983, p. 1096.)

20 3162A SDSNH: Carlsbad Research Center, gently dipping (3–5° SW), locally faulted sequence of blue-gray sandy claystone with interbedded, well-cemented sandstones exposed during development of industrial park, fossils collected through a 70+ ft. section, stratigraphic horizons denoted by letter "A" being lowest, section was best exposed along Palmer Way approx. 2000 ft. W of intersection with El Camino Real (no longer accessible), 33°8′2″N lat., 117°16′41″W long., San Luis Rey Quad., Carlsbad, San Diego Co., Calif. Coll.: B.O. Riney, May 1982, with permission of Koll Company. Rosario Formation, Point Loma Member. Early Maastrichtian.

8 A-3216 UCB: In banks along Los Baños Creek, SE¼, SE¼, NE¼ sec. 12, T11S, R9E, Volta Quad., Merced Co., Calif. Moreno Formation, Volta Sands. Mid Maastrichtian.

8 A-3262 UCB: W branch of small draw a short distance N of large unnamed gully about 3.5 mi. S of Ortigalita Creek near intersection of S border sec. 1 and meridian 120°50′W, approx. 700 ft. E of SW cor. sec. 1, T12S, R10E, Charleston School Quad., Merced Co., Calif. Coll.: A. Bennison, December, 1939. Laguna Seca Formation. Danian.

14 3268 UCLA: Olive silts exposed along banks of small gully about 3 mi. NE of Santa Catarina Landing and ¼ mi. S of the channel of Arroyo Santa Catarina, 5.9 km N, 5.9 km E of Santa Catarina stream at Pacific Ocean, N 18° W of Punta Canoas, Baja California, Mexico. Coll.: W.P. Popenoe & party, February, 1949. Rosario Formation. Early Maastrichtian.

11 3298 UCLA (= CIT 1006): Between Basin Hollow and Clover creeks, Millville Quad., Shasta Co., Calif. Member V. Santonian. (Popenoe, 1957, p. 448.)

5 3623 UCLA: Chico Creek, Paradise Quad., Butte Co., Calif. Chico Formation, Musty Buck Member. Early Santonian. (Matsumoto, 1960, p. 155.)

5 3624 UCLA: First ravine to S of Mickey's Place on W side of Chico Creek about 500 ft. upstream

from UCLA 3622 and 100 ft. below fork in ravine, 800 ft. N, 900 ft. E of SW cor. sec. 1, T23N, R2E, Paradise Quad., Butte Co., Calif. Coll.: L.R. & R.B. Saul, 1952. Chico Formation, Musty Buck Member. Early Santonian.

5 3633 UCLA: E of Chico Creek county road, Paradise Quad., Butte Co., Calif. Chico Formation, top of Musty Buck Member. ?Late Santonian, *Baculites capensis* Zone. (Matsumoto, 1960, p. 15, 156.)

5 3635 UCLA: On E bank of Chico Creek W from $^{H}_{B}$ House and approx. 400 ft. S of twin meadows, 1800 ft. S, 400 ft. E of NW cor. sec. 13, T23N, R2E, Paradise Quad., Butte Co., Calif. Coll.: L.R. & R.B. Saul, 1952. Chico Formation, basal Ten Mile Member. Early Campanian.

5 3637 UCLA: Chico Creek, Paradise Quad., Butte Co., Calif. Chico Formation, Ten Mile Member. Early Campanian. (Matsumoto, 1960, p. 15, 156.)

5 3641 UCLA: Chico Creek, Paradise Quad., Butte Co., Calif. Chico Formation, Ten Mile Member. Early Campanian. (Saul, 1983, p. 121.)

5 3643 UCLA: Chico Creek, Paradise Quad., Butte Co., Calif. Chico Formation, middle Ten Mile Member. Early Campanian zones of *Submortoniceras chicoense* and *Turritella chicoensis holzana.* (Saul, 1974, p. 1093.)

5 3647 UCLA: E side Chico Creek up ravine which is 1.7 mi. from Ten Mile House site by Chico Creek county road, leached fossils in ss approx. 150 ft. up ravine from county road and near large block of basalt, 1750 ft. S, 2750 ft. E of NW cor. sec. 35, T23N, R2E, Paradise Quad., Butte Co., Calif. Coll.: L.R. & R.B. Saul, 1953. Chico Formation, Ten Mile Member. Late early Campanian zones of *Submortoniceras chicoense* and *Turritella chicoensis.*

17 3814 UCLA: Dark gray calcareous ss stringers in buff ss in gully channel 250 ft. N of private road on Lang Ranch, 2800 ft. N, 175 ft. W of SE cor. sec. 26, T2N, R19W, Thousand Oaks Quad., NW end Simi Hills, Ventura Co., Calif. Coll.: D.H. Dailey, 1958. Chatsworth Formation. Early Maastrichtian.

2 4082 UCLA (= CIT 1038): Tuscan Springs, Tuscan Springs Quad., Tehama Co., Calif. Chico Formation. Early Campanian. (Saul, 1978, p. 57.)

11 4104 UCLA (= CIT 1034): Hard, cemented ss slabs weathering out of siltstone in pasture a little W of N of Hathaway Ranch house, about 1500 ft. S, 1400 ft. E of NW cor. sec. 16, T32N, R2W, Millville Quad., Shasta Co., Calif. Coll.: W.P. Popenoe, 1959. Member IV. Coniacian.

11 4106 UCLA: Clover Creek, Millville Quad., Shasta Co., Calif. Member VI. Early Santonian. (Popenoe, 1983, p. 760, 765.)

11 4107 UCLA: Ss in bed of South Cow Creek, about 4400 ft. W of Hunt Ranch House and just downstream from old ruined iron bridge over creek, 1700 ft. S, 2100 ft. W of NE cor. sec. 17, T31N, R2W, Millville Quad., Shasta Co., Calif. Coll.: W.P. Popenoe, 1954. Member V. Santonian.

13 4207 UCLA (= CIT 976): S side Williams Canyon, El Toro Quad., Santa Ana Mts., Orange Co., Calif. Williams Formation, lower Pleasants Sandstone Member. Late Campanian. (Matsumoto, 1960, p. 99.)

11 4209 UCLA: N side of Clover Creek valley along SW slope of NE trending hill, 1300 ft. N, 500 ft. W of SE cor. sec. 31, T32N, R2W, Millville Quad., Shasta Co., Calif. Coll.: W.P. Popenoe, 1954. Member IV, siltstone with interbedded fossiliferous concretionary sandstone slabs. Coniacian.

11 4217 UCLA: Clover Creek Millville Quad., Shasta Co., Calif. Member VI. Late Santonian. (Popenoe et al., 1987, p. 99.)

20 4898 LACMIP: Near base of east-facing road cut opposite Madonna Hill Guest Home, 5392 El Camino Real, 0.85 mi. N of Palomar Airport Road, San Luis Rey Quad., San Diego Co., Calif. Coll.: G.L., C.B. & L.M. Kennedy & W. & L. Hindes, 1973. Rosario Group, Point Loma Formation. Early Maastrichtian.

10 B-5323 UCB: S side Punta San Jose, next promontory eastward from one on which old fish camp is located and at end of road on point; promontory at UCB B-5322 blocks travel along beach except at lowest tides, approx. 2 m strat. below UCB B-5322 and farther E along beach, Baja California, Mexico. Coll.: E.C. Allison & F.H. Kilmer, 1957. Rosario Formation. ?Early Maastrichtian.

10 5431 UCLA: Siltstone and sandstone exposed in littoral zone and 10 to 20 ft. above high tide, S side Punta San Jose, about ½ mi. E of the point and 30 mi. airline S of Ensenada, Pacific coast of Baja California, Mexico. Coll.: W.P. Popenoe & W.V. Sliter, 1965. Rosario Formation. Early Maastrichtian.

23 5795 USGS: Whalers Creek, about 2 mi. from Chignik Lagoon. Series of sandstones about 100 ft. below the coal. Alaska Peninsula. Coll.: W.W. Atwood, 1908. Chignik Formation, Lower Member (Martin, 1926, p. 304). Campanian, *Inoceramus schmidti* Zone.

23 5796 USGS: North side of Chignik Bay 1 mi. N of base of sand spit, Alaska Peninsula. Coll.: W.W. Atwood, 1908. Chignik Formation, Lower Member (Martin, 1926, p. 304). Early Campanian, *Inoceramus schmidti* Zone.

8 5902 UCLA: In gullies tributary to Oil Canyon at its source, just W of center of sec. 7, T19S, R15E, Joaquin Rocks Quad., Fresno Co., Calif. Coll.:

W.P. Popenoe, 1949. Panoche Formation, "Ragged Valley Shale," about 200 ft. above contact with Joaquin Rocks Member. Early Maastrichtian, *Pachydiscus* (*Neodesmoceras*) *catarinae* Zone and Goudkoff's E Zone.

11 5990 UCLA: Sandstone cropping out in bed of small NW-ward-flowing gully tributary to French Creek, near S end of Swede Basin, 300 ft. S, 1800 ft. E of NW cor. sec. 9, T33N, R2W, Millville Quad., Shasta Co., Calif. Coll.: W.P. Popenoe, 1959. Member IV. Coniacian.

14 6368 Blocks fallen from bluffs, first large point N of Punta Canoas, about 3 mi. S of Santa Catarina Landing, Baja California, Mexico. Coll.: Weir, Gugnian & Stager, Feb. 14, 1948. Sepultura Formation. Early Selandian.

8 6496 UCLA: Approx. 1¼ mi. SW of Howard Ranch and ½ mi. N of Romero Creek, 2700 ft. N, 2160 ft. W of SE cor. sec. 21, T9S, R8E, Pacheco Pass Quad., Merced Co., Calif. Coll.: F.A. Schilling, Jr., 1958. Panoche Formation, boulder in conglomerate 8200 ft. below top. Santonian.

14 6534 UCLA: S side of short cul de sac having prominent bare vertical outcrop on N side, W side Arroyo Santa Catarina almost opposite road into Arroyo, approx. 8.1 km N, 4.2 km E of mouth of stream NW side Arroyo Santa Catarina, N 19° W of S tip Punta Canoas, Baja California, Mexico. Coll.: L.R. Saul, R.L. Saul & W.P. Popenoe, 1968. Rosario Formation, buff silts below gritty sands with fossils, cobble conglomerate above. Early Maastrichtian.

8 A-6618 UCB: Moreno Grande concretionary sandstone along road in S bank of Ortigalita Creek in SW¼, NE¼, NW¼ sec. 28, T11S, R10E, Ortigalita Peak Quad., Merced Co., Calif. Coll.: L.I. Briggs, 1948–49. Moreno Formation. Early Maastrichtian.

17 6670 UCR: E side Meier Canyon, 3030 ft. SW 20° from hill 1314, Calabasas Quad., Simi Hills, Ventura Co., Calif. Coll.: W.J. Zinsmeister, 1974. Santa Susana Formation. Early "Martinez" probably = early Selandian.

18 7003 UCLA: East end of Little Sucia (SW islet of Sucia Is.) approx. 200 ft. S from N side of islet and at base of northern E-facing cliff outcrop, sec. 26, T38N, R2W, Orcas Island Quad., San Juan Co., Wash. Coll.: R.B. Saul, 1972. Cedar District Formation, ? just below *Hoplitoplacenticeras.* Mid Campanian.

8 7059 USGS: Foothills between Ortigalita and Little Panoche creeks, about 4 mi. SE of mouth of Ortigalita Creek, on hilltop in NW¼, NE¼ sec. 12, T12S, R10E, about 1500 ft. SW of 875 ft. hill, Ortigalita Peak Quad., Merced Co., Calif. Coll.: R.W. Pack & R. Anderson, 1910. Moreno Formation, within 100 ft. of base of lower gray sandstone. Mid Maastrichtian.

16 7110 UCLA: N side of Garapito Creek just above 1300 ft. contour, 900 ft. N, 725 ft. E of SW cor. sec. 33 (proj.), T1N, R16W, San Vicente y Santa Monica Grant, Topanga Quad., Santa Monica Mts., Los Angeles Co., Calif. Coll.: J.M. Alderson, 1983. Tuna Canyon Formation, upper sandstone. Late Campanian, zones of *Metaplacenticeras pacificum* and *Turritella chicoensis pescaderoensis.*

22 7137 UCLA: Fossiliferous, hard calcareous concretion from ss beds in graben(?) (*Coralliochama* beds in sea cliff on both sides of graben?), about 200 ft. eastward along shore from sandy ravine with road to beach, N side Punta Banda Peninsula, Baja California, Mexico. Coll.: J.M. Alderson, 1984. Rosario Formation. Early Maastrichtian.

12 7149 UCLA: Fossils at beach level from sea cliff exposure approx. 2 km S of San Antonio del Mar, Baja California, Mexico. Coll.: Victor Miller, 1984. Rosario Formation. Early Maastrichtian.

20 7792 LACMIP: 5 m from base of a temporary cut bank which has exposed 17 m of section, N side Faraday Ave., E of intersection with Rutherford Road, approx. 3570 ft. N, 9730 ft. W of SE cor. San Luis Rey Quad., Carlsbad Research Park, Agua Hedionda Grant, San Diego Co., Calif. Coll.: James Loch, spring 1984. Rosario Formation, Point Loma Member. Early Maastrichtian.

20 7962 LACMIP: Carlsbad Research Park, cut bank N side of Faraday Ave. W of intersection with Rutherford Road, W of fault of unknown offset, approx. 3575 ft. N, 9770 ft. W of SE cor. San Luis Rey Quad., Agua Hedionda Grant, San Diego Co., Calif. Coll.: James Loch, spring 1984. Rosario Formation, Point Loma Member. Early Maastrichtian.

24 8159 LACMIP (= CIT 1824): Shales in canyon back of mine office of Gladding McBean Co. North Mine. This is the foot wall of fault by mine, N½, NE¼ sec. 1, T8S, R7W, Cañada Gobernadora Quad., Orange Co., Calif. Coll.: C.R. Stauffer, 1945. Williams Formation, Pleasants Sandstone Member. ?Late Campanian–?early Maastrichtian.

21 31325 CAS: Head of Buckeye Creek, north branch of creek SE of Lee Bow Well, sec. 22, T12N, R3W, Rumsey Quad., Rumsey Hills, Yolo Co., Calif. Basal Forbes?, float from lower conglomerate. Late Santonian or early Campanian.